Popular Astronomy.

Vol. VII. No. 6. JUNE, 1899. Whole No. 66.

THE SPHERES OF ACTIVITY OF THE PLANETS.

F. R. MOULTON.

FOR POPULAR ASTRONOMY.

A short article by Professor Asaph Hall in the April number of POPULAR ASTRONOMY, under the above heading, suggests this paper. The "sphere of activity" which we shall consider, is one surrounding a planet outside of which a satellite cannot permanently revolve without passing away to the Sun. In seeking for new satellites there will be no use of looking for them at greater distances from the planets than the limits given here, and very probably they will be found, if at all, considerably within these limits. The definition of the "sphere of activity" in Professor Hall's paper, is not such that conclusions of this sort can be reached with certainty.

I am sure Professor Hall will excuse me for making a few explanatory remarks on his article, which treats a subject of much interest. A careless reader, who neglects to observe the meaning of the formulas, might infer from one of his sentences that a "sphere of activity" is the locus of points where the attractions of the Sun and planet are equal. In reality, the formulas express the condition that the ratio of the attraction of the Sun to that of the planet shall equal the ratio of the attraction of the planet to the disturbing action of the Sun. The final approximate formula would have been the same if the condition had been written, that the ratio of the attraction of the Sun to the disturbing action of the planet, should equal the ratio of the attraction of the planet to the disturbing action of the Sun. It will be observed that this is quite a different thing from the locus of points where the attractions of the Sun and planet are equal. For example, it is well known that the Sun's attraction for the Moon is always much greater than that of the Earth, and consequently the surface of equal attractions is entirely within the Moon's orbit; while, on the contrary, Professor Hall found that the radius of the Earth's "sphere of activity" is 501,700 miles, or twice as great as the Moon's distance from the Earth.

This emphasizes very strongly the difference between *attrac-*

tion and *disturbing force*. The disturbing force depends upon the difference of attraction upon the two bodies. Thus, while the Sun's attraction for the Moon is very great, it is nearly the same for the Earth, and the disturbing effect is not so great as to prevent the Moon's orbit around the Earth being nearly an ellipse. On the other hand, the Earth does not exert such a powerful attraction on the Moon, but its disturbing effect on the motion of the Moon around the Sun is very large, because the Sun is relatively so far away.

Laplace was led to give the definition of "spheres of activity," used by Professor Hall, in his theory of the motion of comets in the neighborhood of planets. When a comet is very near a large planet, the planet exerts the predominating influence determining its motion. In the comet's approach toward the Sun it will have attained such a velocity by the time it comes in proximity to the planet, that the velocity is hyperbolic with respect to the planet as a center of force. In this case, where the planet's attraction predominates, and where the comet moves at hyperbolic velocity with respect to the planet, Laplace found it advantageous to treat the problem as though the comet were describing an hyperbola around the planet, and to regard the Sun as a distant disturbing body. When the comet is at a considerable distance from the planet, it is regarded as describing a conic section around the Sun with the planet as a disturbing body. It is natural to change from one method of treatment to the other, as Laplace did, at the place where the ratio of the Sun's attraction to the disturbing action of the planet is equal to the ratio of the planet's attraction to the disturbing action of the Sun.

The locus just defined, as Professor Hall remarked, is not exactly a sphere, but on the contrary the locus of equal attractions is a sphere. This subject seems to be of sufficient interest to justify a still further digression to develop it. Pass a plane through the Sun and planet. Take a system of rectangular axes in this plane with the origin at the planet, and the positive x-axis directed to the Sun. Represent the distance from the planet to the Sun by a. Let m represent the mass of the planet and S that of the Sun. Let (x, y) be any point at which the attractions of the Sun and planet are equal. The condition is,

$$(1) \qquad \frac{m}{x^2 + y^2} = \frac{S}{(a - x)^2 + y^2}$$

This reduces to the form,

$$(2) \qquad x^2 + y^2 + \frac{2ma}{S - m}x = \frac{ma^2}{S - m}$$

This is the equation of a circle whose center is on the x-axis at a distance $\frac{ma}{S-m}$ from the center of the planet in the direction opposite to the sun, and whose radius is,

$$R = \frac{a\sqrt{Sm}}{S-m} \tag{3}$$

Rotating the planet around the x-axis the circle generates a sphere which *is the locus of points where the attractions of the Sun and planet are equal.*

In the *Astronomical Journal*, No. 461, in a paper entitled, "*The limits of temporary stability of satellite motion, with an application to the question of the existence of an unseen body in the binary system, F. 70 Ophiuchi*," I have defined a sphere surrounding a planet, outside of which a satellite *cannot revolve* without passing away to the Sun. The reasoning upon which the definition is based is too complicated to be reproduced here, but it may be stated that the determination of each radius involves the solution of a quintic and a cubic equation. However, a simple approximate formula may be found. Take for unit of length the distance of the planet from the Sun, for unit of mass the mass of the planet, letting S represent the mass of the Sun in the same units. Then with sufficient approximation the radius of the sphere of the planet's activity defined in this way is,

$$R = \frac{2}{3(3S+1)^{\frac{1}{3}}} \tag{4}$$

The second part of my paper in the *Astronomical Journal* treats the question of the existence of a dark star in the binary system F. Ophiuchi. About three and one half years ago, Dr. T. J. J. See computed the orbit of this binary. Not being able to get the theory to represent the observations well, he came to the conclusion that the motion of the companion is disturbed by a dark satellite. His views were expressed in a number of papers on the subject. My investigation shows that it is impossible for a dark satellite to move in the manner supposed, and we are forced to the conclusion that there is no unseen body in the system, having such a mass, and moving as Dr. See found it convenient to assume.

It will be of interest to make a comparison of the radii of the planets' "spheres of activity" as defined by Laplace and by formulas (3) and (4). In the table given below, column (A) gives the radii of the "spheres of activity" as defined by Laplace.

The figures are taken from Professor Hall's paper. Column (B) gives the radii of the spheres outside of which satellites cannot permanently revolve. It is computed from (4). Column (C) gives the radii of the spheres of equal attraction and is computed from (3). The results are expressed in miles.

	(A)	(B)	(C)
Mercury,	55,700	87,000	21,000
Venus,	325,000	419,000	105,000
Earth,	501,000	620,000	149,000
Mars,	316,000	449,000	81,000
Jupiter,	26,000,000	22,000,000	15,000,000
Saturn,	29,000,000	27,000,000	15,000,000
Uranus,	28,000,000	29,000,000	12,000,000
Neptune,	47,000,000	48,000,000	20,000,000

It will be noticed that the columns (A) and (B) are substantially the same, although it could not have been foreseen from the definitions. The irregularities in the differences may be due, in part, to the differently varying effects of the approximations employed.

The limits in the cases of the inferior planets are less for the reason that their masses are smaller, and also because they are nearer to the Sun. At the beginning of the evolution of a planet-satellite system, the masses and velocities might be so distributed that the tides on the planet would drive the satellite beyond this *limit of stability*. Other things being equal, the limit would be passed sooner for planets near the Sun than for those remote, and this suggests the idea that Venus and Mercury may have had satellites in the remote past which have been driven outside of the planets' "spheres of activity" by the action of the tides. As Darwin has shown in his masterful researches on Tidal Evolution, the tides would also retard the rotations of the planets; so, it is possible that the periods of revolution and rotation of Venus and Mercury are respectively equal as a consequence of the action of satellites now escaped, as well as of the retarding effects of the tides raised by the Sun. This theory would make less strange the great difference in the rotation periods of Venus and the Earth. Still, it must be understood that this hypothesis is advanced as being a possibility, and not as possessing any great degree of probability.

It is proper to ask what would become of an escaped satellite. No certain answer can be given to that question, but it is probable that sooner or later it would either fall into a planet or the Sun, or, pass so near to one of them that it would be disintegrated. The course of events would doubtless be very different with satellites leaving the various planets.

In considering the tidal evolution of a planet and satellite, it is always necessary to include the effects of the tides raised by the Sun. They retard the rotation of the planet, as well as those produced by the satellite, and thus help to bring about an equality between the period of rotation of the planet and revolution of the satellite. It is clear then, that this final condition of equality of period, in which the tides do not directly effect the motion of the satellite, will occur with the satellite less remote from the planet than it would if the Sun were not also raising tides. The problem of determining just how far a satellite will recede from a planet when the action of the tides raised by the Sun is also included is one of very great difficulty, and especially so when there are several satellites attending the same planet. If this question were answered it might show, in connection with the "spheres of activity" defined above, that the planets will eventually lose all of their satellites except, of course, the inner one of Mars which is approaching the planet. This would be less likely to result if the satellite were small, for then the solar influence would be the more important.

The table given above furnishes the limits of the distances from the planets beyond which satellites cannot exist. For the purposes of the observer they should be expressed in arcs. The following table gives the maximum angular distances that satellites can be from their respective planets as seen from the Earth, and is, of course, computed supposing that the Earth and planet are in conjunction.

	°	′		°	′
Mercury,	0	5	Saturn,	1	57
Venus,	0	55	Uranus,	0	59
Mars,	0	44	Neptune,	1	1
Jupiter,	3	13			

It is conceivable that the satellites have still smaller satellites attending them, as they attend the planets. In fact, satellites of the Moon have frequently been sought for, especially during lunar eclipses. Let us apply our "sphere of activity" test and find the limit outside of which a satellite to the Moon could not exist. Regarding the Moon as revolving around the Earth, and neglecting the disturbing action of the Sun, we find, $R = 25{,}000$ miles.

Including the disturbing action of the Sun, which would operate at times in the same direction as that of the Earth, we see that the real limit would be considerably less than 25,000 miles. Hence, we conclude that if a satellite to the Moon is ever found, it will not have an elongation greater than four or five degrees.

THE UNIVERSITY OF CHICAGO, 1899, May 15.

DETERMINATION OF POSITIONS OF OBJECTS NEAR THE BORDERS OF A LARGE PHOTOGRAPHIC PLATE.

S. C. CHANDLER.

For Popular Astronomy.

Occasion will often arise to find the precise place of an object, like an asteroid or a comet, situated at a considerable distance, say two or three degrees, from the center of a photographic plate. If there is a considerable number of catalogue-stars, within half a degree or so of the object, which it is desirable to utilize for this purpose, the rigorous solution of this problem entails much labor which can be curtailed by the following process, if one is not over-fastidious about errors of 0″.05, a quantity in general much below the accidental errors of observation and of the catalogue-places of the determining stars.

Let α_0, δ_0 be an approximate assumed place of the unknown object, and $\Delta\alpha_0$, $\Delta\delta_0$ the corrections to be determined. Let A_0, D_0, be the R. A. and Decl. of the center of the plate, and α', δ', the catalogue-place of one of the determining stars. Put

$$A = (\alpha_0 - A_0)\ \text{sinl}'', \qquad D = (\delta_0 - D_0)\ \text{sinl}'' \tag{1}$$

then compute, with four-place logarithms merely,

$$\left.\begin{aligned}
A_1 &= 10^3 \left(\frac{1}{2} D^2 + \frac{1}{2} A^2 (3\cos^2\delta_0 - 1)\right)\\
A_2 &= 10^3 (AD - A\tan\delta_0)\\
A_3 &= 10^6 \sin 1'' \left(D - \frac{1}{2}\tan\delta_0\right)\\
A_4 &= 10^6 \sin 1'' \frac{1}{2} A (3\cos^2\delta_0 - 1)\\
A_5 &= 10^6 \sin 1'' (-A\tan\delta_0 \sec\delta_0)\\
D_1 &= 10^3 \frac{1}{2} A \sin 2\delta_0\\
D_2 &= 10^3 \left(D^2 + \frac{1}{2} A^2 \cos 2\delta_0\right)\\
D_3 &= 10^6 \sin 1'' A \cos 2\delta_0\\
D_4 &= 10^6 \sin 1'' \frac{1}{4} \sin 2\delta_0\\
D_5 &= 10^6 \sin 1'' D
\end{aligned}\right\} \tag{2}$$

For each catalogue-star find with $\Delta\alpha = \alpha' - \alpha_0$, $\Delta\delta = \delta' - \delta_0$, the differences from the assumed place of the object to be determined, ΔX, ΔY, in rectangular coördinates, by means of

$$\left.\begin{aligned}\delta X \sec \delta_1 \sin 1'' &= \Delta\alpha + A_1[\Delta\alpha] + A_2[\Delta\delta] + A_3[\Delta\alpha][\Delta\delta] \\ &\quad + A_4[\Delta\alpha]^2 + A_5[\Delta\delta]^2 \\ \Delta Y \sin 1'' &= \Delta\delta + D_1[\Delta\alpha] + D_2[\Delta\delta] + D_3[\Delta\alpha][\Delta\delta] + \\ &\quad D_4[\Delta\alpha]^2 + D_5[\Delta\delta]^2\end{aligned}\right\} \quad (3)$$

where $\delta_1 = \frac{1}{2}(\delta' + \delta_0)$; and the bracketed values $[\Delta\alpha]$, $[\Delta\delta]$ are expressed in terms of 1000″ as unity.

Let $\Delta\xi$, $\Delta\eta$, be the measured differences in rectangular coördinates, of each star from the unknown object, reduced with an approximate assumed value in seconds, of screw or scale, with the plate approximately oriented.

Put $$n = \Delta X - \Delta\xi, \qquad n' = \Delta Y - \Delta\eta \qquad (4)$$

Then each star will give two equations of the form

$$ax + by + \Delta\alpha_0 \cos\delta_0 = n, \qquad ax' + by' + \Delta\delta_0 = n' \qquad (5)$$

where $$a = \frac{\Delta X}{1000'}, \qquad b = \frac{\Delta Y}{1000} \qquad (6)$$

The numerical work involved in computing, once for all, the coefficients in (2), and the substitution for the several, stars in (3) to find ΔX and ΔY, is much less (where, as usually, there are from eight to a dozen available comparison-stars) than by the use of the rigorous trigonometrical formulas, which require X and Y to be computed for all the objects, accurately with seven-place logarithms, from

$$\left.\begin{aligned}\tan K &= \frac{\cos(\alpha - A_0)}{\tan\delta} \\ X &= \frac{\tan(\alpha - A_0)\sin K}{\sin(D_0 + K)\sin 1''}, \quad Y = \frac{1}{\tan(D_0 + K)\sin 1''}\end{aligned}\right\} \qquad (7)$$

and then the differences to be taken between the unknown and comparison-stars to get ΔX, ΔY.

To show the facility of the process an example is taken from a plate for which M. Prosper Henry has given the materials (*Bull. du Comité Int. Perm.*, 2nd *Fasc.*, *T.* II), although it does not fully illustrate the advantages of the method, which is intended and adequate for cases where the group of stars is several degrees from the center of the plate, whereas it is here only about six-tenths of a degree.

The center of the plate is at $A_0 = 1^h\ 4^m$, $D_0 = +24^\circ$. The approximate place of the star *1* to be determined, is assumed $\alpha_0 =$

$1^h\ 1^m\ 41^s.00$, $\delta_0 = +\ 24°18\ 10''.0$. The places of the comparison-stars are

	α' h	m	s	δ' °	′	″
a	0	59	31.38	+ 24	25	18.2
b	0	59	59.37	23	26	51.1
c	1	1	1.05	24	22	9.7
d	1	2	4.61	24	26	21.5
e	1	3	52.92	23	55	30.1

We have from (1), $\log A = n8.004681$, $\log D = 7.723001$. Also the following lagarithms for use in computing (2).

A^2 6.0094	A^3 n4.0140	$\cos\ \delta_0$	9.95970	$\sin 2\delta_0$	9 8752	$\frac{1}{2}$	9.6990
D^2 5.4460	D^3 3.1690	$\tan\ \delta_0$	9.6547	$\cos 2\delta_0$	9.8204	10^3	3.0000
		$3\cos^2\delta_0 - 1$	0.1736	$\sin 4\delta_0$	9.9965	10^6 sin 1″	0.6856

Then from (3) we find

$$\left.\begin{aligned} \Delta X \sec \delta_1 &= \Delta\alpha + 0''.090\,[\Delta\alpha] + 4''.511\,[\Delta\delta] \\ &\quad - 1''.069\,[\Delta\alpha]\,[\Delta\delta] - 0''.037\,[\Delta\alpha]^2 + 0''.024\,[\Delta\delta]^2 \\ \Delta Y &= \Delta\delta - 3.''793\,[\Delta\alpha] + 0.''062\,[\Delta\delta] - 0.''032\,[\Delta\alpha]\,[\Delta\delta] \\ &\quad + 0.''909\,[\Delta\alpha]^2 + 0.''026\,[\Delta\delta]^2 \end{aligned}\right\} \quad (8)$$

The determination of $\Delta X \sec \delta_1$ and ΔY from (8) is exemplified for star *a*, as follows,

	″		″
$\Delta\alpha$	− 1944.30	$\Delta\delta$	+ 428.20
	− 0.17	$\Delta\delta$	+ 7.37
	+ 1.93		+ 0.03
	+ 0.90		+ 0.03
	− 0.14		+ 3.44
	0.00		0.00
$\Delta X \sec \delta_1$	− 1941.78		
log	n3.288200		
$\cos \delta_1$ (24° 21′ 44″)	9 959497		
ΔX	− 1768″.88	ΔY	+ 439″.07

The values of ΔX and ΔY for all the stars, and also those of $\Delta\xi$, $\Delta\eta$ given by the measurements, as well as n and n' by (4) are as follows:

	ΔX ″	ΔY ″	$\Delta\xi$ ″	$\Delta\eta$ ″	n ″	n' ″
a	− 1768.88	+ 439.07	− 1776.86	+ 424.30	+ 7.98	+ 14.77
b	− 1398.63	− 1271.11	− 1407.06	− 1284.75	+ 8.43	+ 13.64
c	− 544.92	+ 242.34	− 554.62	+ 227.32	+ 9.70	+ 15.02
d	+ 324.49	+ 490.31	+ 315.51	+ 476.04	+ 8.98	+ 14.27
e	+ 1803.23	− 1363.78	+ 1793.39	− 1376.25	+ 9.84	+ 12.47

whence the equations of condition, by (5) and (6), for determining $\Delta\alpha_0$ are

					″
− 1.77	x	+ 0.44	y	+ $\Delta\alpha_0 \cos \delta_0$	= + 7.98
− 1.49	"	− 1.27	"	"	= + 8.43
− 0.54	"	+ 0.24	"	"	= + 9.70
+ 0.32	"	+ 0.49	"	"	= + 8.98
+ 0.18	"	− 1.36	"	"	= + 9.84

The equations for determining $\Delta\delta_0$ are the same, substituting x', y', $\Delta\delta_0$, as the unknowns, and n' as the absolute term.

The solution gives

	$\Delta\alpha_0 \cos\delta_0$	$+ 9''.37$		
	$\Delta\alpha_0$	$+ 0^s.658$	$\Delta\delta_0$	$+ 14''.01$
Hence	$\alpha = 1^h\,1^m$	$41^s.658$	$\delta = +24°\,18'\,24''.01$	

It may be remarked that the rigorous formulas (7) give values differing in no case more than $0''.05$ from those found above: also further that the form of equation of condition (5), including four unknowns, $x\ y\ x'\ y'$, for the plate-constants, will, as has been shown by Turner, give $\Delta\alpha_0$, $\Delta\delta_0$, free from aberration as well as from differential refraction so far as the latter can be assumed to vary proportionally over the region covered by the group of stars measured. This will be the case generally for moderate zenith-distances, say under 60°. Finally it should be noted that for high declinations, say much over 60°, the rigorous equations (7) are required in any case, since the attempt to include the terms neglected in (2) would complicate them too much for practical use.

I have had occasion recently to apply the above process to cases where the distances from the center were as large as three degrees, and have found it so useful that it has seemed worth while to print the method in POPULAR ASTRONOMY for the benefit of its readers who may have similar applications to deal with.

THE PARALLAX OF THE GEGENSCHEIN.

J. EVERSHED.

FOR POPULAR ASTRONOMY.

Professor Barnard in his very interesting and instructive article on the gegenschein in POPULAR ASTRONOMY, No. 64, refers to my explanation of this object, which assumes it to be a tail to the Earth of escaping hydrogen and helium, analogous to a comet's tail.

This theory Professor Barnard promptly annihilates by the remark that the absence of any parallax is fatal to it.

The question of parallax was carefully considered by me before publishing my theory, and I regret that I did not allude to it in my letter to the Observatory. I think, however, that if Professor Barnard will reconsider the conditions of the case he will agree with me that the absence of any observable parallax does not in any way invalidate my theory.

My point is this: I assume that the length of the Earth's tail is not of the order of hundreds of thousands of miles, but rather of tens of millions! And that parallax can only affect the nearer portion, which moreover is hidden in the Earth's shadow.

This assumption as to length is justified by the analogy of cometary tails. Probably no self-respecting comet has ever ventured within our system with a tail of less than a million miles! The very beautiful photographs of these objects which Professor Barnard has obtained show that many of the fainter comets are possessed of extraordinary long tails, and it is needless to mention the great sun-grazing comets whose tails at perihelion stretch out for a hundred millions or so of miles.

In referring to the simultaneous observations of the gegenschein made in Northern and Southern latitudes Professor Barnard concludes that "had the gegenschein been an actual object at a distance *not greater* than the Moon the observations would doubtless have indicated its parallax." Now, according to my theory, I suppose that what we see as the gegenschein is in reality the integration of the light reflected from gaseous molecules situated at varying distances along the axis of the tail. But the nearer portion of the latter, say within the Moon's distance, would be completely blocked out by the Earth's shadow, whilst the greater proportion of the light would be contributed by particles situated at vastly greater distances than the Moon. It is evident, therefore, that the centre of the gegenschein would be practically unaffected by parallax, even if its position could be located with considerably greater accuracy than is possible with so ill-defined an object.

With regard to the *apparent* distance of the gegenschein I would like to ask Professor Barnard whether he can state any definite reason for his belief in the nearness of the light from mere visual estimate? He says that "it does not seem to him to be extremely far away."

But is there any possible means of forming even an approximately correct judgment of the distance of such an object as the gegenschein by eye alone? There can be no question here of the parallactic or focal adjustment of the eyes, which under ordinary circumstances, by an unconscious cerebral process, is supposed to give one a more or less correct notion of distance.

Through the courtesy of Mr. Evershed, I have been permitted to see the above note.

Perhaps I did Mr. Evershed an injustice in stating that the ab-

sence of any appreciable parallax in the gegenschein was fatal to his theory, because any theory that in any way goes to explain the phenomenon should be encouraged, for there is little enough that is satisfactory in the previous attempts to explain it.

The observations show that the gegenschein is frequently as much as 20° in diameter. It is evident from this that if it is a tail to the Earth it could not be hidden in the Earth's shadow for any very great distance as Mr. Evershed supposes. It therefore still seems to me that we should have a decided parallax throughout the night from the nearer portions of the "tail."

It would seem also that the shadow of the Earth ought to be seen projected on the gegenschein if Mr. Evershed's theory is correct—an objection which I believe some one has already offered.

Mr. Evershed is quite correct in questioning my statement that the gegenschein "does not seem to be extremely far away." I do not think anyone can tell much about the distance of an object of this kind from its looks alone, and I can not explain the statement further than to say that the object δ impresses me with a sense of nearness—which is no explanation at all! Perhaps, however, the impression is in part due to the very great size of the gegenschein. E. E. BARNARD.

1899, May 8.

RE-DISCOVERY OF TEMPEL'S SECOND PERIODICAL COMET *c* 1899.

C. D. PERRINE.

FOR POPULAR ASTRONOMY.

This comet was re-discovered by the writer on May 6, with the 36-inch refractor of this Observatory. Its position at the time of rediscovery was May $6^d\ 21^h\ 47^m\ 4^s$ Gr. M. T.

$$\alpha = 18^h\ 52^m\ 57^s.78, \qquad \delta = -4^\circ\ 32'\ 19''.1$$

A comparison of this observation with Schulhof's ephemeris, published in No. 3554 of the *Astronomische Nachrichten*, showed the following very small derivations—

Obs.—Comp. $\alpha, -5^s.61$ $\delta, -12''.9$

The comet is very small and faint, not being over 10″ in diameter and from 15½—16 magnitude. It is brighter at the center with some indications of a nucleus.

It was discovered first on July 3, 1873, shortly after passing

perihelion, by Wilhelm Tempel, at Milan. It was soon found to be of short period and has been observed at the returns of 1878 and 1894.

The comet appears to be decreasing rapidly in brightness from a comparison of the various apparitions. At the time of discovery it was described by Tempel as faint but a few days later is described as over 5′ in diameter and much brighter. At the last observation in 1878, its theoretical brightness as deduced from the formula $\frac{1}{r^2\Delta^2}$ was 0.113; in 1894, at the time of its discovery, Finlay describes it is 11th magnitude or fainter, while its theoretical brightness was 0.190; at its present appearance its theoretical brightness is 0.475 and its observed brightness 15½—16 magnitude. It must be remembered that comets do not follow this law of brightness very closely but in the present case the discrepancies are larger than usual.

The comet is well situated for observation from Earth at the present return and in July will be only about a third the Sun's distance from the Earth.

The disturbing action of Jupiter on comets is well shown in this instance, the time of perihelion being retarded more than 15 days although the comet did not approach that body nearer than 1.9 units.

LICK OBSERVATORY, University of California.

1899, May 9.

THE FUNCTION OF CRITICISM IN THE ADVANCEMENT OF SCIENCE.*

FRANK HAGAR BIGELOW.

We now pass to comment briefly on the second canon of identity, namely, whether the material is *new or old*. This is a precept which is becoming of increasing importance as the matter of scientific investigation accumulates, and with serious acceleration as time goes on. The immense mass of papers which must be examined before it is safe to pronounce a thing new in any subject is already becoming a source of anxiety to students. It is indeed the primary cause of the specialization now going on so rapidly, by which one man becomes an expert in a very limited field of work, but at the same time undergoes a process of isola-

* Continued from page 261.

tion from his fellow-workers. It is perhaps necessary to submit to this accumulation of literature, because the human mind seems capable generally of only relatively small improvements at a time upon the work of predecessors, except in the rare instance of a genius being produced by the grand process of nature. Sometimes a vein is falsely exploited, sustained by the pretension of novelty and the desire to acquire a reputation, as when an author deliberately gives a well-known subject some slight twist, which persists throughout his exposition, while in reality the work contains no genuine new contribution to science. Also several men may have been working quite independently of one another and thus have brought forth similar results by means of different courses of procedure. At any rate, we can all see that the necessity of a scientific clearing-house is becoming essential not only for the convenience, but also for the real progress of science. There is need that in the subjects which have been practically cleared up there should be some authoritative statement regarding the final product of such investigations. Some attempt has been made towards this in two or three directions: (1) by means of the short summaries which certain journals of substantial purpose are publishing; (2) by the institution of congresses or conferences of specialists, who shall pronounce regarding certain definite subjects and be responsible for tables of constants, formulæ, as well as nomenclature. The very growth, however, of knowledge makes the task set for the standard journals increasingly difficult, because the reference summaries are meager and there must necessarily be an immense and increasing number of them. The work of our congresses or international committees is also unsatisfactory, because the labor of bringing many men to the same point of view regarding intricate questions is very great, and, indeed, so impracticable that in fact only few advanced problems, and usually only simple questions, can be treated in this way.

In my judgment, the best plan to pursue would be for experts to train themselves thoroughly in special directions, so that they can study up, digest, and classify certain branches of knowledge once for all, and thus leave to their successors all the real information there is, expressed in short space and in language recognized as standard. If this generation has been prolific of a multitude of research men, the time may not be far distant when advanced work will be limited to the few who have developed special knowledge and peculiar instinct for such progress, and when, simultaneously, a number of students shall unify and simplify to

the utmost the real residuum of facts and laws. For this latter purpose we need first of all a standard international system of notation in mathematics and physics, by which it will become perfectly easy to pass from one man's writing to another's, so far as the use of coördinate axes, letters, and symbols to represent fixed quantities and relations are concerned. I have taken the trouble, indeed it has been a necessity for me to do so, to rearrange the symbols in my texts on meteorology and terrestrial magnetism in a uniform notation, to the great assistance of scholarship and pleasure in studying these subjects; for there is nothing more annoying than to acquire the ideas of one author in certain equations, and then on passing to another author who has written on parallel lines to find the same ideas and facts expressed in terms just enough different to make every equation and combination look strange. It is also a surprise, after these subjects in a half a dozen books are reduced to one notation, to find how widespread the tendency is to go over the same ground again and again and yet with no real advance beyond suggestions as to minor details, which occur incidentally and only as subordinate aspects of the same truth.

Thus we find in (1) Barometry the attempt to put Laplace's equation in a dozen different forms, which neither advance in any respect the real subject of the variation of the air pressures with the height, while in fact all these can well be summarized in one system, such as the International Committee proposed; in (2) the Thermodynamics of the atmosphere, the fundamental relations are capable of being stated in one comprehensive scheme, which shall supplant all the papers now referred to, and wherein there is much repetition of work; in (3) Terrestrial Magnetism there are a half a dozen schemes of coördinates and notations now afloat, whereas by reference to three standard canons the entire subject can be made to read as one; in (4) Electricity and Magnetism, what a diversity of formulæ have been derived from *Maxwell* on the one hand and from *Helmholtz* on the other, forming now the English and the German schools; in (5) Astronomy and Geodesy there is the same divergence of processes springing from the several works of the original investigators, which yet might be reduced to one simple and comprehensive system. It seems to me that we must soon have a clearing-house of these fundamental matters, carried out radically and comprehensively. Then all authors should write their works in the adopted system, on the penalty of not being published at all. Much pretentious new knowledge will thus be found to be old, and all recognized advances will be substantial.

We must hasten over the second canon of newness and oldness, to spend the rest of our limited time on the fascinating topic suggested by the third case, namely, that of rank in the hierarchy of knowledge. This comprises the assignment of relative merit to those requirements of science which as individual facts, laws, and theorems are sound, and have passed through the two antecedent stages of criticism. In illustration of this principle, it may be profitable to call attention to one of the most important and interesting struggles for supremacy that has arisen in the history of the development of science. There may be some features of this topic which are not sufficiently familiar to those who have never made a special study of these subjects, to make it particularly easy to understand fully the merits of this controversy, but probably the main features can be readily apprehended.

It may seem going very far apart to seek in the Ptolemaic system of astronomy, and the chemical theory of phlogiston, the remote beginnings of this modern strife, but that is apparently where it unconsciously began. There are three systems of astronomy which form the stages in the development of our modern science—the Ptolemaic, the Copernican, and the Newtonian. In the Ptolemaic system the stars and the planets were all regarded as having real motions about the Earth, assumed itself to be at rest; in the Copernican system the Sun is the center of motion, while the Earth and the other planets rotate on their axes and revolve about it; in the Newtonian system all celestial motions are due to the operation of the one law of universal gravitation. In addition to the plausible account given of the observed motion of the stars and planets by the first system, its real strength consisted in the ancient difficulty of conceiving how the atmosphere, how men, and all other things could remain on a rapidly rotating sphere without sliding off. The fact which really broke down the theory was the incontestible one observed by sailors, that the surface of the sea was not flat, but that their ships descended from view. The heliocentric theory of Copernicus not only showed that the celestial motions could be as well accounted for by it as by the Ptolemaic system, and more simply, but that it also contained greater possibilities of knowledge. The observations of *Copernicus*, *Tycho*, and *Kepler*, giving rise to *Kepler's* three laws, culminated in the central law of gravitation, and *Newton's* three laws of motion. Herein the law of rank is superbly realized, and its crown, universal gravitation, is destined to endure at the head.

Another point that puzzled men so long was, How can a body keep moving about another continuously without some additional force to sustain the motion in its path? Only gradually did the great truth emerge, through the suggestions of *Leonardo da Vinci*, *Galileo's* law of falling bodies, and *Huyghens'* theory of central forces, till *Newton* was able to define it in the laws of inertia, composition forces, and mutual action. The splendor of these conceptions excited the imagination of the best minds, not only to extend the sphere of observation but also the purely mathematical analysis of all sorts of mechanical problems. The contribution of *Laplace*, *d'Alembert*, *Lagrange*, *Hamilton*, and many astronomers, whose names are immortal, have certainly carried out the promise of Newton's laws to splendid fulfillment. Along with the success attending these achievements, there grew up the conviction that the entire range of phenomena in the universe, great and small, can be finally reduced to some part of the theory of mechanics. With this object in view, all problems in physics, in chemistry, and even in mental psychology, have been attacked along the lines of mathematical mechanics. What shall we now say—with success? That is the very question to which I desire to direct your attention.

Along with the satisfactory solution of many problems which, though great in themselves, are only minor parts of a more comprehensive subject, the human mind has gradually gone onwards from the study of the operations of nature, as embodied in certain laws, to an investigation of what is behind the law itself—the forces, the energy, the ultimate substance, out of which the material world is built. For if the law of gravitation is known, what about the gravitating force itself—its origin, nature, and operation? What about molecular and chemical forces in themselves? What about the nature of heat energy, kinetic and potential energy, work energy, electric and magnetic energy? What about the ether, the atoms, action at a distance or through a connecting medium? The mere mention of these modern questions is sufficient to recall the vague suspicion which has been recently overspreading the scientific world, that perhaps after all mathematical mechanics is going to fail of its ultimate mission. For I have only to remind you that the great modern masters, *Maxwell* and *Helmholtz*, definitely abandoned the use of the purely *mechanical* equations, and attained their advances by the employment of the more comprehensive *energy* equations; and also to note that their disciples, *J. J. Thomson*, *Heaviside*, *Hertz*, *Planck*, *Boltzmann*, *Helm*, and others, are

working these problems from the energy point of view and not from the purely mechanical. The trouble has been two-fold. In the first place, the mathematical equations become too complicated for operation outside the province of simple geometrical points in their mutual interrelation; and in the second place, there is coming to realization the fact that the fundamental things of this universe are not so simple as the geometers would have them. The two laws of thermodynamics, with their expressions of conservation of energy, namely, the impossibility of creating energy or destroying it, and the impossibility of transforming energy except under certain definite conditions, have given rise to a new reach of knowledge apparently as high above the three Newtonian laws of motion, as these are above the Ptolemaic fear that man would slip off this Earth if it were round. It is now about as difficult for us to perceive how it can be that the collision of gas molecules is maintained without the addition of some outside forces, as it was for the churchmen of Galileo's day to see how a planet can continue to circle about the Sun without some outside force acting on it to push it along.

Let us now go back to our other starting point, the theory of phlogiston, and advance to the general point of view, namely, the struggle between mechanics and energetics, which we wish to more fully explain. The history of the development of our ideas of energy, from the theory of phlogiston to the laws of intensity and capacity, is one of the most fascinating and instructive accessible to the student of science. The phlogistic theory, invented by *Stahl* at the end of the seventeenth century, was in vogue for about one hundred years, till *Lavoisier* overthrew it finally. It maintained the notion that every combustible substance contained an inherent principle which it lost during com bustion. Hence all combustible substances are compounds-Charcoal, coal, sugar, flour, &c., are rich in phlogiston. The actual escape of flame from a burning substance as a visible something, the uncertainty of the nature of heat, and the idea that it is a form of imponderable matter, caloric, gave the theory its strength. Besides, no other theory was known which could take its place. Oxygen was dephlogisticated air because it was capable of taking more phlogiston from nitrous air, and therefore must itself contain less of the principle. Nitrogen was phlogisticated air because it could give up the burning material.

This theory fell under the blow which *Lavoisier* dealt it with his balances. He weighed his gas and found that what one lost on entering into chemical combination, the other gained in

weight. He found that air consisted of a mixture of two gases, one of which could support combustion, while the other could not. He proved that water was a compound of hydrogen and oxygen, uniting in definite proportions. His opponents, the adherents of the phlogiston theory, *Priestly*, *Cavendish*, did their best to break the force of these experiments; but they never succeeded, and the theory perished with them, so far as phlogiston is concerned.

The similar theory of caloric had a life for nearly 50 years longer, till about 1845, when *Joule* by experiment proved the mechanical equivalence of heat and work; in other words, that heat, no more than the principle of combustion, is a substance. Having arrived at this negative proposition, it is not too much to say that after 50 years more of eager study we do not yet know what heat is, although we have discovered much about the operations of nature roughly classified as heat. The story of this attempt to solve the main problem is worth repeating (Compare Energetik, *Helm*). The discovery that combustion must be ascribed to a process and not to a substance, and the later proof that heat is a process and not a substance, brought up the entire range of questions involved in natural process, and with them the study of the primary problems: What is force? What is energy? A long controversy arose over the proper measure of force. Some said, It is the motion generated, and hence where there is no motion there is no force. Others claimed that the acceleration of motion, the rate at which velocity of motion changes, is the true measure of force, and these still hold the field. *Helmholtz* defined energy as $E = \frac{1}{2}mv^2$ in 1847. It had already been surmized that heat is a form of motion. *Hobbes* thought that light and heat had a common origin in motion; *Locke* that heat is only motion; *J. Bernouilli* had the conception of the conservation of energy; *Daniel Bernouilli* suggested the kinetic theory of gases; Count *Rumford* boiled water by means of friction only; *Humphrey Davy* melted ice by rubbing two pieces over each other; *Fresnel* showed that light and heat are interchangeable; *Mohr* discussed the transformation of forces; *Lagrange* found the dynamic equation of a conservative system of forces. The practical mechanicians soon saw that the transformation of forces leads to the idea of the conservation of energy. *Poncelet* took as the measure of work a force operating through a given space and proved the principle of the transmission of work. This principle, work $= Fds$, is the

ground of the energy conceptions, and from it comes the theorem of the mechanical equivalence of heat and work. *Robert Mayer*, 1842, laid down these concepts: "Energy is indestructible;" "energy has variable manifestations;" "energy is imponderable." He also distinguished clearly "potential and kinetic energy." These concepts have dominated the thought of the past 50 years, but recently we are trying to do away with the distinction between potential and kinetic energy, as an incomplete statement of a greater truth. *Rumford*, *Carnot*, *Mayer*, *Colding*, *Joule*, *Clausius*, and others have sought the mechanical equivalent of heat in various ways, and it turns out to be about 426.8 kilogram-meters or 777.9 foot-pounds for this latitude.

Helmholtz sought to ground a theoretic basis for the transformation of energy in the principle of the "impossibility of perpetual motion," and showed that the mode of transformation, such as a *Carnot* cycle, does not affect the result, but at first he was unsuccessful in arriving at an analytical expression. He then introduced the further principle of action and reaction, which is equivalent to limiting the operation of his cycles to central forces, and proved that rotations as well as translations must be taken into the account, and thus arrived at the famous theorem of the conservation of energy: "In the conservative systems, the sum of the kinetic and the potential energies is a constant." *Helmholtz* made an application of his principle to magnetic, electric, and heat processes, but fell into another error, and his result met only with opposition, showing how hard it is even for a master mind to successfully grasp at the outset the truths of nature's operations. Another thread of the problem was worked out by *Carnot*, *Clausius* and *Thomson*, culminating in the entropy theorem, which, coupled with the theorem of conservation, gives the two laws of thermodynamics. Stripped of all technicalities, the first or conservation law is, that energy cannot be created or destroyed by mechanical processes; the second or entropy law is, that the energy of a body can be transformed only from higher to lower states of intensity. The first law asserts that the sum total, or the energy of the universe, is constant; the second that the available useful energy of the solar system is diminishing in efficiency.

It cost much labor and effort to arrive at the true mathematical expression for the second law. The early investigators, *Carnot*, *Clayperon*, and *Horstmann*, did not emancipate their minds from the erroneous idea that heat is a substance, caloric. *Carnot* knew that heat and work were transformable quantities,

but, supposing that heat is an indestructible substance, he never went beyond the incorrect statement that heat is equivalent to the work done. He did not know about the entropy function, which connects the quantities of heat energy and work energy. *Clayperon* followed *Carnot's* error, and the differential equation which they adopted as fundamental is erroneous, since they supposed they were dealing with a true differential, which was not the case. *Carnot* introduced the fruitful idea of reversible and irreversible cycles; *Clayperon* used the indicator diagrams to measure the value of the work expenditure in a complete reversible cycle. To *Clausius* and *W. Thomson* (Lord Kelvin) belongs the credit of the discovery of the entropy function and the analytic form of the same. *Clausius* first used the word entropy in 1865, but the idea was complete in 1855. *Thomson* began his work on this subject with *Carnot's* idea, but in 1850 abandoned that view of the relation of heat and work. First he defined the absolute temperature, then he relinquished *Carnot's* statement that in doing work heat as a substance does not lose in quantity, but only in aspect, and accepted *Clausius*, proposition that heat is a molecular movement, which in doing work loses quantity as well as changes in aspect.. *Carnot* had, however, this correct idea, that the kind of medium through which the work is done is not essential, but only the initial and final temperatures, for otherwise perpetual motion would be possible. *Clausius* admitted that the small changes in the intrinsic energy, the heat energy, and the work energy are not true differentials, but only small variations.

Thomson reaches the relation, $\frac{AW}{Q_2} = \frac{\theta_1 - \theta_2}{\theta_2}$ where A is the mechanical equivalent of heat;

W is the work performed;

Q_2 is the heat transformed at the higher temperature, θ_1, θ_2 being the lower temperature.

There follows from this, $S = \int_{z_0}^{z} \frac{dQ}{\theta}$ $\quad dQ = \theta dS.$

The expression, $dS = \frac{dQ}{\theta}$, is called the entropy law, and was put in its final form by *Planck*. It shows that the entropy must increase for a given expenditure of heat operating at a fixed temperature, or if the entropy is held constant, the temperature

must be lower. Hence the entropy of the world tends towards a maximum, or the temperature of the world is running down towards a minimum. Since this formula applies only to *Carnot's* reversible processes, we find that for all irreversible processes the expression is $dQ < \theta dS$, and hence the complete expression of the second law of thermodynamics is $dQ \leqq \theta dS$. For the first law we have $dE \leqq \theta dS + dA$, where dE is the change in the intrinsic energy, θdS that in heat energy, and dA that from all other sources, the sign of equality holding for the reversible processes and the sign of inequality for the irreversible processes.

I may well apologize for going so far into technical expressions, but the importance of the conclusion in view is such that I beg your indulgence for a very few moments longer. When the principles suggested by the second law of thermodynamics are applied to the other processes of nature, it is found that nearly every region of phenomena falls under the same general form, and that taken together they make up one great principle, of which $dQ = \theta dS$. is the type. The following table is compiled from *Helm's* Energetik, 1898, and embraces heat, kinetic and potential mechanical energy, central and cyclic work, surface and volume energy, terrestrial and universal gravitation, frictional and chemical energy, electric and magnetic energy, electric and magnetic polarization:

Forms of energy.	Intensity.	Capacity.	Change in energy.
Q Heat.	θ Absolute Temperature.	S Entropy.	$dQ = \theta \,.\, dS.$
$\mathfrak{T}$ Kinetic energy.	x^1 Velocity.	mx^1 Force.	$d\mathfrak{T} = x^1 \,.\, d(mx^1)$
U Potential energy.	V Potential energy.	m Molar mass.	$dU = V \,.\, dm.$
A_0 Work (cyclic).	$2\mathfrak{T}$ Kinetic energy.	$\log q$ Cyclic moment.	$dA_0 = 2T \,.\, d \log q$
A Work (central).	X Force.	X Distance.	$dA = X \,.\, dx.$
A_ω Surface energy.	P_1 Surface tension.	ω Surface.	$dA_\omega = P_1 \,.\, d\omega.$
A_τ Volume energy.	P Pressure.	τ Volume.	$dA_v = P \,.\, d(-\tau).$
W Terrestrial gravity.	h Height.	gm Weight.	$dW = h \,.\, d(gm).$
Z Universal Gravitation.	$\frac{M}{r}$ Potential.	m Mass.	$dZ = \frac{M}{r} \,.\, dm$
R Friction.	v Velocity.	K Resistance.	$dR = v \,.\, dK.$
C Chemical energy.	H Chemical intensity.	M Chemical mass.	$dC = H \,.\, dM.$
E_e Electric energy.	F Electric tension.	ε Electricity.	$dE_e = F \,.\, d\varepsilon.$
E_H Magnetic energy.	Ω Magnetic tension.	H Magnetism.	$dE_H = \Omega \,.\, dH.$
D Displacement.	J Electric current.	i Electric density.	$dD = J \,.\, di.$
B Induction.	G Magnetic current.	N Magnetic density.	$dB = \Delta \,.\, dN.$

Lagrange's Law (energetics). $$\frac{d}{dt}\left(\frac{\delta(T-U)}{\delta p'}\right) - \frac{\delta(T-U)}{\delta p} = P,$$

external force tending to increase p.

d'Alembert's Law (mechanics). $\int_{t_0}^{t_1} \Sigma(Xdx + Ydy + Zdz) = T_1 - T_0$, increase of energy.

I. Helmholtz's Law. $T + U = H$ = conservation of energy.

II. Intensity and capacity Law. $dE = J.dM$ = transformation of energy.

This analysis of phenomena shows that variations of energy in their transformations are known only as the product of two terms. Of energy itself, the primal quantity, we know nothing as yet. Whether it ever can be known to man remains to be seen. Of the two factors which measure the change in energy, the first is called the intensity and the second the capacity. Examples of intensity are the absolute temperature, velocity of motion, the potential function, the double kinetic energy, force, surface tension, pressure, height, the Newtonian potential function, chemical intensity, electric and magnetic tension, electric and magnetic currents. These quantities are the guages of the condition of the substance through which the work of the transformation of the energy is performed. Thus the temperature or pressure of a body prescribes the amount of the work required to produce a given rise in its heat or volume respectively. Now, the prerequisite that there shall be any transfer of energy whatsoever is that there must be differences of intensity in contact with each other. For any transfer of heat there must be two bodies in contact having different temperatures, as hot and cold pieces of metal; or two bags of air with different pressures, which are spherical before contact, but become deformed on touching each other, the bag of lower pressure yielding more than the one at higher pressure. Next, the transfer of energy is always from the substance of higher intensity to the one of lower intensity, as from the hot to the cold body, from the high pressure to the low pressure body. The second law of thermodynamics therefore becomes general by saying that every energy form endeavors to go over from a higher to a lower intensity. This is the intensity law and is universally applicable, so far as now known.

The second factor in energy changes is called the capacity, and examples of it are entropy, force, molar mass, the cyclic moment, distance, surface, volume, weight, resistance, chemical mass, electricity, magnetism, electric and magnetic density. The capacity measures the amount of the energy transferred from one body to another. If intensity measures the amount of the disturbance of

equilibrium, and conditions the rate at which the transfer of energy takes place, the capacity measures the amount of energy that is transferred when the form of energy is changed. Hence under the law of conservation the amount of energy that one body loses the other gains, and therefore the sum of the capacities taken throughout the process is constant. The amount of heat one body loses the other gains in the new equilibrium; the amount of pressure one body loses the other gains, in order that equilibrium may be restored. If this equilibrium is disturbed by some change in the intensity, then the capacity measures the amount of energy that can transfer under these circumstances, and the total energy transformed is the product of the intensity and the variation of the capacity.

It may seem strange that the terms that we employ freely—force, mass, surface, volume, weight, electricity, and magnetism—are only forms of this capacity function, and that they are apprehended only during the instantaneous transfers of energy. It may cause surprise to perceive that the other set of terms we commonly talk about as entities, namely, temperature, velocity, potential and kinetic energy, height, pressure, tension, current, are perceived only during the transfer of energy; and it may be difficult to realize that we know nothing of heat, kinetic and potential energy, work, gravitation, friction, chemical, electric, and magnetic energy in their entities, but only in their processes of transfer. Energy is the great unknown entity and its existence is recognized only during its state of change. It may be surmised that we are here on the borderland of profound metaphysical speculations which we have no opportunity to enter upon at this time.

For our immediate subject in hand, namely, the illustration of the third canon of criticism, that every valid and new fact or law must be assigned to its proper rank in the hierachy of science, we see at once that the foregoing analysis is of special significance. Here are more than a dozen examples from the processes of nature which can be classified under one comprehensive general law, whose principle once fully comprehended makes it possible to critically analyze a multitude of subordinate statements regarding the details of thought and theory which are found in current scientific literature.

The above law has been stated as an equality $dE = J.\, dM$, but this is applicable only to the cyclically reversible phenomena. Now there is the second great class of phenomena, called the irreversible, which are not cyclic; that is to say, if a certain state

exists in a body at an initial moment, and if after going through transformations it can be brought back to the same state again, it is reversible; but if it cannot return to that state, it is irreversible. Now there are many forms of energy-transfer which are irreversible; that is where the energy is wasted, so far as the efficient value of it is concerned, as where heat is lost by dissipation, electric and magnetic energy by radiation. Hence there is the law of dissipation of energy as well as the law of conservation, and the dissipation of the higher power energy seems to be the dominant practical fact in the world around us.

Let us glance backward once more to a previous statement regarding the onward march of mechanics as the means of solving the physical problems of the universe. At first, under the influence of astronomy and mechanics of large masses, there was every prospect of its success; but when these principles were applied to molecular or atomic masses, and to physical laws of greater complexity, the difficulties of the mathematicians and physicists began, and they nave continued to be insuperable to this day. The essence of the mechanical theory is *d'Alembert's* law of work, that force operating through a distance is the measure of such work, $dA = X.ds$. *Lagrange's* equation of work is derived by essentially ignoring spacial coördinates and substituting the parameters (intensities) which determine the condition of a substance while coupling it with the other quantity (capacity) which denotes the direction of the change. In doing this two steps are involved: (1) the potential energy of the mechanical system is ignored or thrown out of consideration, and the kinetic potential is alone employed; (2) the change in kinetic energy is assumed to be equal to the change in the energy of the system. In a word, all energy is kinetic, and no energy is potential—that is, after all the grand change from the mechanical system to the energy system of treatment. *Lagrange* made it possible by his equation; *Maxwell* first recognized the importance and necessity of this reformation, and out of it came his splendid electric and magnetic equations; *Helmholtz* adopted the same plan and found the laws of the cyclic and reciprocal system; *Hertz*, in his great treatise on modern mechanics, excludes the potential energy from his system; *J. J. Thomson* has successfully applied this method to a great number of physical problems, and he says, "We may look upon the potential energy of any system as kinetic energy arising from the motion of systems connected with the original system, and from this point of view all energy is kinetic, and all terms in the Lagrangian func-

tion express kinetic energy, the only thing doubtful being whether the kinetic energy is due to the motion of ignored or positional coördinates" (Dynamical Methods, p. 14). *Poincare* states, "I have demonstrated that the principles of thermodynamics are incompatible with mechanical principles of direct action and action at a distance; also mechanism is incompatible with the theorem of Clausius." *Helm* makes a long argument in favor of the view that energy transformations cannot be explained by mechanical analysis of the most advanced type. All this applies to the type of reversible or cyclic processes; but in the case of the irreversible or acyclic phenomena, even this law of *Clausius* is not available, for *Poincare* states (Thermodynamique, p. 422), "It results from this that irreversible phenomena and the theorem of *Clausius* are not explicable by means of *Lagrange's* equations." In a word, the first law of thermodynamics may have some mechanical analogues, but in connection with the second law there are no such analogues from mechanics. *Heaviside* has made a very stout effort to secure such analogues for electric and magnetic relations, but each type has ended in some irreconcilable difficulty, and therefore no such analogues are known. The attempts of *Lodge*, *Boltzmann*, and others to illustrate the electric and magnetic phenomena by means of mechanical pictures must always be considered under the reservation that they can be only partially true.

I have thus attempted to give some idea of the battle royal between mechanics and energetics that is now going on, and have indicated that the banners of mechanics are certainly drooping, and that their standard-bearers are weary. Whether energetics is to be the final victor, or whether some stronger idea will be discovered, remains beyond the forecast of to-day. It looks now as if science were fast approaching those impenetrable mysteries which have confronted the metaphysician and the theologian for centuries; it seems certain that the attempt to construct this universe out of pure matter and the three simple laws of force is a failure; it may not be improper to assert that the available energy for doing useful work is being expended and that the world's supply is running down. There arises further questions: Where did energy spring from originally? What keeps up the supply, if it is now running down? What is to be the final state of things when the supply has gone? If the universe in its physical processes is really exhausting itself, what is this theory of evolution by which it is claimed that some combinations of energy, animal and human life, organic life, is coming up? Is inorganic

life running down, and is organic life coming up? If this is so, what is the difference? In fact, what is life? Is mechanics destined to give place to energetics, and is energy finally to become tributary to the science of life whose first law has not yet been discovered? If not this, what is the true hierarchy in the existences, and does the pathway lead up from man and his little spark of life to some immense oversoul, and is that life the substance of the temporary phenomena we call this world?

THE ORBIT OF Δ 15.

H. B. EVANS.

For Popular Astronomy.

This close pair was discovered by Dembowski in 1869, and since that time the position angle has apparently changed through an angle of about 165°. The following observations have been plotted to scale in the diagram:

1870.44	5*n*	Dembowski
1876.54		"
1876.68		"
1877.44		Spörer
1881.42	3*n*	Burnham
1893.54	2*n*	Leavenworth
1895.26	3*n*	Barnard
1896.46	4*n*	Leavenworth
1897.36	4*n*	Aitken
1897.74	3*n*	E. Doolittle
1899.28	2*n*	E. Doolittle

The observations are not discordant, but are not favorably arranged. On this account and also on account of the smallness of the change in position angle, an exceedingly small amount of accuracy can be expected to accompany any attempt at an investigation of the orbit. Nevertheless some idea of the motion may be thus obtained. A discussion of the observations by the method of Kowalsky led to the following results:

$$P = 109^{y}$$
$$T = 1897.8$$
$$a = 1''.24$$
$$e = .55$$
$$\omega = 157°$$
$$i = 72°$$
$$\lambda = 201°$$

The apparent ellipse due to these elements has been plotted on the diagram. The closeness with which it fits the observed positions is mainly due to the small number of the latter. A better

idea of the agreement of this orbit with the observations can be obtained from the differences between the observed and computed position angles. All but four of these are less than one degree.

A reduction of the observations by the method of Klinkerfüss gave about the same position elements but a period of less than half that given above. Whether the above elements represent in any way the true orbit, can not be told for some time. If there is any accuracy in them, it is evident that observations at the present time will be very valuable in determining it.

FLOWER OBSERVATORY,
May 16, 1899.

A POPULAR ASTRONOMICAL OBSERVATORY.*

GEORGE E. LUMSDEN.

The expediency of establishing and maintaining a popular astronomical Observatory at Toronto, is a subject which may be discussed under two heads, arranged as questions:—

"Of what may a popular Observatory consist?" and

"How may such an Observatory be acquired and maintained?"

We shall simplify matters if we clear the ground by stating that a popular Observatory to be a success must be intended for instruction only and not for research, at least not for research that demands very powerful telescopic assistance. Except in certain branches, original research may be left to great refractors and reflectors, remote from the smoke and heat of cities, the glare of electric lights, and the vibratians of rushing trains. Large instruments are sadly out of place in the immediate neighborhood of cities, and are useless for the purposes of popular instruction. At seats of learning fully equipped for astronomical observation, the practical, every-day work is done with telescopes of moderate aperture, though more powerful instruments be available.

Every astronomical observer finds himself beset by two classes of local conditions, which must be taken into account: meteorological and atmospherical. The former class has to do with the clearness of the skies; the latter with the steadiness of the air. The one may keep the Observatory closed, the other, to a greater or less degree, may interfere with sharpness of definition.

* From the Publications of the Astronomical and Physical Society of Toronto.

If the meteorological conditions at Toronto were such that telescopes could be used every night, one might be able to be more patient under the pressure of a demand in certain quarters for large instruments. But the records of the Observatory show that, in every year, the percentage of cloudy skies at Toronto is always greater than the percentage of clear skies. In 1896, the last year reported, there were but three months in which the clear weather was even slightly, if at all, in excess. The average of cloudiness in 1896 was 60 per cent.; in 1895, 57 per cent.; in 1894, 60 per cent.; in 1893, 59 per cent.; in 1892, 61 per cent.; in 1891, 59 per cent.; in 1890, 62 per cent. The average for the past forty-three years was 61 per cent., so that 1896 was not a very bad year. During that year, however, 55 days were entirely clouded, and, of the 365, there were only 74 which could be reported "fair," a term which does not indicate that the skies were even clear. If, therefore, we are to make the most of our opportunities, we must have recourse to small telescopes, which are less exacting as to atmospherical conditions, and can be used during nights when, by reason of haze, cloudiness and air-currents, large instruments must perforce stand uncovered in their domes.

The atmosphere is ever in a state of unrest.* Terrestrial objects radiate heat, which rises in waves and floats with the wind. Vapors and air-currents possess peculiar properties of refraction. By them, celestial objects are distorted. Outlines suffer from tremors and a rippling effect technically known as "boiling." The larger the telescope the more are these atmospherical disturbances magnified and exaggerated. When present even in a slight degree, they are troublesome. When pronounced and persistent, the only value of great light-gathering power is counterbalanced, if not destroyed. Images must be well defined; mere brightness counts for nothing. Large telescopes are invariably designed for the discovery of unknown orbs. But obstacles of a grave nature too frequently confront the observers who use them. The comparatively tranquil and sharply defined images seen in small instruments are not present in very large ones. Objects are much more brilliant, but are involved in glare, and subject to constant agitation. The finer details are often obliterated. Another serious difficulty is due to the flexure, or "sagging," of the heavy discs forming the object-glasses or mirrors of great telescopes. For these reasons, there have been many failures. The list of

* See, generally, "Telescopic Work for Starlight Evenings," by W. F. Denning, F. R. A. S., p. 20, et seq.

"disappointments" includes the Lord Rosse 6 and 3-feet reflectors, which, owing to the climate, can be used "at their best" only during a few hours annually, and the 4-foot Paris reflector, which, on the average, can be employed advantageously not more than one night in the year. The Herschel 4-foot, the Lassell 4-foot, and the Melbourne 4-foot reflectors, and the Vienna 27-inch, the Leander McCormack 26-inch, the Washington 26-inch, the Gateshead 24-inch, the Princeton 23-inch, and the Nice 30-inch refractors have not, by any means, realized anticipations. Usually, observers with these instruments are conscious that the advantage gained in light has been lost in definition. On rare occasions, perhaps once in fifty times, results are different. The atmosphere is approximately at rest. Objects are sharply defined, as in smaller telescopes. The astronomer realizes that his instrument, though generally ineffective, is itself not at fault, and that it would do valuable work were the conditions of the air always, or more often, suited to the exercise of its full powers. Dr. Kitchener, after testing 51 instruments, held the opinion that large telescopes were as useful as the enormous spectacles suspended over the doors of opticians, and asked, "What good can a great deal of bad light do?" His conclusion was that amateurs of astronomy should seek perfect, rather than large telescopes. Professor Young, of Princeton, who has charge of the great refractor of the University, probably said for large instruments as much as could be safely said, when he wrote: "I can almost always see with the 23-inch everything I see with the 9½-inch under the same atmospheric conditions, and see it better; if the seeing is bad, only a little better, if good, immensely better." During the spring of 1885, Young, while observing with the 23-inch, was able only twice to use on Jupiter a power of 1,200 diameters, but he then succeeded in detecting delicate details in and near the Great Red Spot, and in seeing the true forms of certain white dots on the belts of the planet. In perfect air his telescope should easily bear a power of 100 to the inch of aperture, or a power in excess of, at least, 2,000, but, ordinarily, a much lower power than 1,200 must be employed. It is this absence, at most places, of proper atmospheric conditions which has driven several Observatories to mountain heights, where the air is always pure and often free from cloud and vapor. Harvard College, which possesses the most complete Observatory in the world, has a branch in the mountains of Peru. The Percival Lowell Observatory, at Flagstaff, Arizona, and the Swift Observatory in Southern California, are two others which claim to possess the advantages of clear mountain air.

Small instruments have done a vast amount of useful work in every field of astronomical observation. Even as to nebulæ, which require great space penetrating power, D'Arrest shewed what small apertures can accomplish. Every department is indebted, more or less, to common telescopes. Their good work is due to the efficiency with which they can be used despite conditions that very often render great instruments valueless. Nearly all the comets and double-stars were discovered with them. With the exceptions of the discovery of the moons of Mars, the fifth satellite of Jupiter and the motion of nebulæ in the line of sight, very little that is noteworthy, can, of late years, be credited to great telescopes. Herschel said that an object may be seen with less optical power than was required for its discovery. And this is true. Only after a long and arduous search, which would have been given up but for his wife, was Hall able to satisfy himself that Mars has two moons, though he employed the 26-inch telescope of the Washington Naval Observatory, the largest refractor then in existence. These moons, which had escaped Herschel with his 4-foot reflector, are now comparatively easy objects in a good 7-inch refractor. After a prolonged search, Barnard, using the 36-inch Lick telescope, espied the fifth satellite of Jupiter, but, once discovered, the Moon was found to be visible in much smaller telescopes, including the 18-inch at the Dearborn Observatory, Chicago. Burnham's glory, as a discoverer of difficult double-stars, will be associated, not so much with the 36-inch at Lick Observatory, as with the 6-inch telescope with which, as an amateur, he whiled away his evenings, and with which he made discoveries which astonished observers with better facilities. Langley with a 13-inch made his reputation as a solar observer, and Dawes, one of the most successful amateurs in England, never used a telescope larger than 8-inches in diameter, and usually employed a 4-inch. Schiaparelli, with a 9-inch, discovered the "canals" of Mars, which some very reputable observers cannot see with telescopes two or three times as great in aperture. Satisfy all the conditions as to time, place, position and readiness she demands, and the first-class battleship becomes a terrible engine of destruction, but under average conditions, the trim cruiser can fight all around her, and go where she dare not. At Alexandria, Admiral Seymour, on his flag-ship, was compelled to stand off in deep water, while Charley Berresford, on the *Condor*, ran in shore, silenced the batteries, and did effective work. Satisfy all the conditions as to sky and air that it demands, and the giant telescope becomes

a powerful accessory of the astronomer, but instruments of one-half, or even one-third of its size can, under average conditions, do effective work while it must stand idly by.

An Observatory which would answer very perfectly the popular purposes in view, may, in the writer's opinion, consist of a low, rectangular frame building, equipped with several telescopes of moderate aperture. So far as a building is concerned, all that is absolutely required is a structure which will protect instruments from weather and from dampness. There can scarcely be a greater mistake than that of mounting a telescope in a small building of heavy stone, or brick. It is impossible to maintain the temperature inside and the temperature outside of such an Observatory at the same height, an indispensable requisite, if the telescope is to give satisfactory definition, at least, as soon as it is placed in use. Except on account of dampness, which has a tendency to rust its polished metal parts, it would be best to leave every telescope out of doors, because then the temperature of the air and of the telescope would always be uniform. This uniformity allows the instant use of an instrument at any favorable moment. As is well known, glass quickly responds to changes of temperature, expanding under the influence of heat and contracting under that of cold. Owners of dome-protected telescopes, after uncovering them, are compelled to wait, often through annoying intervals, until the various lenses have cooled sufficiently to enable them to recover their true forms and give the best results. Some astronomers allow their telescopes no other protection than convas affords. Others do not hesitate to leave their instruments in the open air, unprotected save by a heavy coat of paint. Under ordinary circumstances, the temperature within a stone or brick Observatory is some degrees, and in warm weather many degrees, higher than the temperature outside. When the shutters of the dome are opened, counter air-currents are set up, as a matter of course. While these continue, fine definition is simply impossible of attainment—even if the optical parts are in a normal condition. The difficulty in this respect, is further increased if a telescope, as is often the case, be perched in the top of a tower with an inner stairway leading to it.

A low frame building can be made roomy, cool and convenient. Ingress and egress would be easy; there would be no stairs to climb and visitors, as well as observers, could move about freely and with comfort. If sufficiently large, the building could, without much additional expense, be made to provide necessary

rooms and even a public hall for small audiences. A rectangular structure would furnish corner spaces for four domes, under which could be set up at once, if funds allowed, one first-class refractor of, say, eight or ten inches aperture for solar and stellar work, and two first-rate reflectors of, say, fifteen or twenty inches aperature, for lunar, planetary and photographic work, the remaining dome to be reserved for a transit instrument. Great Observatories are exceedingly expensive to erect, equip and maintain. Each of them swallows up several average fortunes. On the other hand, it is possible to erect, equip and maintain a popular Observatory at a cost which, comparatively speaking, would be a mere bagatelle. For instance, a first-class Brashear or Alvan Clark 8-inch refractor can be bought for $2,600; a 10-inch for $3,300, and a 12-inch for $6,000. A Brashear reflector, of the highest quality, and 12½ inches in aperture, would cost $1,550; a 15½ inch, $2,000, and a 20-inch, say, $3,000. Its mounting is very often a very expensive part of a telescope, especially if it be of moderate size; this is always true if the instrument is provided with circles engraved on silver, and with other, partly necessary and partly luxurious, conveniences. For a popular Observatory, great refinement of equipment is not really needed. If omitted from the instruments mentioned, their respective prices would be materially reduced. A 3-inch transit would cost $1,000, a chronograph $400, and necessary clocks $500 more. To these could be added a photographic-doublet, costing about $350, and a spectroscope costing somewhat less. If a site could be secured, $10,000, certainly less than $12,000, would be a sum sufficient to put up the building and set in working order by far the best popular astronomical Observatory on the continent. If arrangements could be effected by which such an Observatory would be taken over by one of the Universities as some return for its use for the purposes of instruction, the maintenance need be of small cost, as the director, himself a professor, could derive ample assistance from his staff and students.

The writer's view has been that, from the standpoint of the public interest, it is better to expend a comparatively large sum upon several instruments of small aperture than upon a single instrument of large aperture. This he knows is, popularly speaking, the view of a heretic. But for the information of those who, in good faith, differ from him, he must add that the cost of large telescopes, whether refractors or reflectors, grows by leaps and bounds as aperture is increased. For instance, as has

been shown, a complete 12-inch refractor may be purchased for $6,000, yet the 36-inch glass discs for the Lick telescope, alone and unmounted, had cost $50,000 before they left the workshop; the incidentals connected with the mounting and housing of the telescope were all extra, and have absorbed nearly $700,000. Reflecting telescopes are, relatively, very much cheaper. The 20-inch reflector, already referred to, would cost $3,000, and, all things being equal, would be an instrument superior to the 12-inch refractor costing $6,000, a sum that would itself go a long way towards paying for a 30-inch reflector, which, when the elements permitted, would do superb work, and would bring to Toronto, even as a matter of possession only, credit and renown. The mounting and housing of these instruments would require additional expenditures of money on a scale rapidly increasing in proportion to size of aperture, but still moderate as compared with those of refractors. On the ground, among others, of expediency, the writer has consulted several directors whose testimony cannot be questioned, some of them having, or having had, charge of telescopes of the largest size and of the highest excellence. These gentlemen all agree that for usefulness and, certainly, for the purposes of instruction and popular work, an Observatory similar to the one above described is undoubtedly best. Dr. Keeler, the eminent spectroscopist, now director of, and for the second time connected with, the Lick Observatory, writes as follows:—"My experience with visitors is that they prefer one large telescope to a number of small ones. They may *see* better with the latter, but it is the size which attracts and satisfies them. Perhaps it is not worth while to humor a notion having so mistaken a basis." Dr. Keeler may have been reflecting upon scenes said to be witnessed on Saturday nights at Lick Observatory and described some years ago by Mrs. Proctor, who has counted as many as two hundred persons waiting their turn to look into the great telescope. One minute's time only was allowed to each visitor. Without practice, this is an opportunity certain to be wasted. Unless one knows what to look for and how to look for it in a telescope, little can be done in one minute. Dr. Holden and his assistants endeavored to reduce to a minimum the disappointment often felt by visitors, but after the trials attending a long drive over a mountain road, and an enforced return at night by stage to hotels fourteen miles from the Observatory, the disenchantment in cases, must have been complete. A gentleman, who was no astronomer, but who had been induced by curiosity to make the long journey to

Mount Hamilton, told the writer that on one of these occasions all he was able to see was "the planet Mars shining like a red-hot plate." But how different was the result under other circumstances—the crowd being away, the conditions being good, and the time of the observer being at his own disposal! Mr. Serviss, the author of that charming book, "*Astronomy with an Opera Glass*," has described to the writer the delight he experienced when, in company with Professor Barnard, he was permitted to observe, at his leisure, and with the great telescope, the fifth satellite of Jupiter, an object up to that time, December, 1893, seen, perhaps, by less than a dozen human beings.

So much as to what a popular Observatory may be, and now as to the sources from which to provide for and maintain such an Observatory.

There are various sources. There is the general public. There is private munificence. There are our universities, which are teaching institutions of which much is expected, and which might take up the matter wholly, or in part with the assistance of the public, a society, or a company, or, as is the most popular way in the United States, of money supplied by wealthy men desirous to assist in disseminating useful knowledge among their less favored fellow citizens. The ideal public Observatory would be an Observatory equipped and maintained as the public library is equipped and maintained, that is, at the public charge, so that every ratepayer, under certain conditions, might enjoy equal rights of admission, if he chose to exercise them. This suggestion may seem to be odd, but such a suggestion will not always be odd. The day may not be far distant when even Legislatures will authorize, if not require, school boards to provide astronomical instruction for the young. There can be no harm, at least, in permissive legislation, similar to that respecting libraries. The cost distributed over a municipality would be very inconsiderable, while the benefits to be derived would be very considerable. The day has come when no seat of learning, certainly no university, or college worthy of the name, can afford to treat astronomy and the physics related to astronomy with disdain, real or affected, or to remain unable to gratify students who take, or could be induced to take, an intelligent, practical interest in the science, but who are deprived of work at the telescope, the charm of which is beyond expression. No man can boast a liberal education and, at the same time, be ignorant of the fundamental principles of astronomy, a science whose influence, especially, on its practical or observational side, has a wholesome,

animating, and elevating tendency. As years pass, more and more time is devoted in Europe and in the United States to this subject, not that every man shall be an astronomer, but that he shall have the opportunity, if he choose, to make some acquaintance with the science. The apathy in this respect now marking educational institutions in Canada was once but too apparent in the United States. In 1825 John Quincy Adams was ridiculed in Congress for urging that a national Observatory be founded. In 1832 Airy told the British Association that, so far as he knew, there was not one Observatory in the Republic. Airy's remark, however, was not without effect. Ormsby MacKnight Mitchell, then professor of mathematics and astronomy in Cincinnati College, it is true, partially for the purpose of increasing his own information, prepared and delivered a course of lectures which created sufficient local enthusiasm to bring into existence the Astronomical Society of Cincinnati, which, in a few years, numbered 800 members. Out of the pioneers, Mitchell, at the very start, formed a joint stock company with a capital of $7,500. This amount was subscribed in three weeks. Mitchell was sent to Europe for a telescope to cost $10,000. Though less than 12 inches in aperture, it was to be the largest on this continent. The instrument was eventually erected in a building whose corner-stone was laid by ex-President Adams, then of an advanced age, and as the last public act of his life. Mitchell, full of enthusiasm, offered to act as director of the Observatory for ten years without salary, depending upon his income from the college. Almost as soon as this magnanimous proposal was agreed to, he was driven again to the lecture platform, fire having destroyed the Cincinnati College and, with it, his means of livelihood. But Mitchell's personal loss was the country's gain. His manly eloquence and sterling qualities as an exponent of science secured for him crowded audiences in all parts of the States, and especially in the east. The results were really astonishing. In ten years ten Observatories had been erected and opened. In 1882, fifty years after Airy's comment, there were 144 in existence. Now there may be 200, three of them outrivalling any others on the face of the Earth. Airy's praise of English munificence, such as it was in 1832, led to that munificence being exceeded one hundred fold in America. An enormous impetus and popularity were, by these means, given to the study of astronomy everywhere. Even women have vied with men in giving lavishly of their money for equipping Observatories, for teaching the science in schools and for assisting in sending out scientific expeditions.

Several practical schemes, each differing a little from the other in the principle which has been worked out, may be here mentioned.

Returning for a moment to the Cincinnati Observatory, it may be stated that after languishing during the Civil War, Cleveland Abbé became its director. In the meantime, the city had encroached upon the Observatory, and, a gentleman having come forward with the offer of a new site and $10,000 for a building, the proceeds of the old site, which was sold, were devoted to endowing a School of Art and Design in connection with the university, the city, as a condition of the gift, agreeing to sustain the Observatory, which was also attached to the university. The State Legislature passed an Act requiring the Board of Education to assess and levy annually on the taxable property of the city not less than three-one-hundredths, nor more than five-one-hundredths, of a mill, a levy which, at the lower rate, though infinitesimal, yields annually about $5,000, a sum which has answered every necessary purpose. In a letter to the writer of this paper, the present director says the Observatory is now an inregral portion of the educational system of the city, and, in reply to an inquiry as to the method by which the Observatory is conducted, adds: "Our present plan, which works well, is to admit visitors on twelve evenings in each month, these being selected by the director and furnished to the university office. Tickets are then issued gratis by the clerk to any one applying up to twenty for each evening. Sometimes the whole number will be taken for a single party, but more often two or three smaller parties are admitted on the same night. As nearly every one wishes to see the Moon, the public evenings are chosen from a couple of days after New Moon or Full Moon. There is no provision for school children, but the classes in astronomy from the different schools often obtain permits and come under the same regulations as other parties. I have a special assistant to take charge of this work. Of course, students who take astronomy in the university, have a little more freedom and have the theory and the uses of all the instruments explained to them. The public understand that the main object of the Observatory is scientific research and that no privileges are granted which will seriously interfere with this." Here we have worked out the principle of the State recognizing an astronomical Observatory as on integral portion of the educational system of a city similar to Toronto in many respects.

Take another instance, that of the Chabot Observatory at

Oakland, California. This ideal public and educational institution, the result of private munificence wisely directed, has recently become a worthy monument to the memory of a worthy citizen. Twelve years ago, Mr. Anthony Cabot, a wealthy resident of Oakland, a small city, was induced by several gentlemen, including the school inspector, to found a popular Observatory which, on completion, was presented to the School Board in trust for the city and was directed to be used to educate the general public and the pupils in the public schools. In 1892, Mr. Chabot was so pleased with the results of his gift that he donated a further sum, in all about $25,000, in order that the Observatory might be rebuilt and improved. The frame building which was erected, in addition to other necessary apartments, includes a lecture-room, 20 by 30 feet in size. The equipment consists of an 8-inch Clark telescope, with micrometer and spectroscope, a mean-time clock, a sidereal clock, a sidereal break-circuit chronograph, a 4-inch transit, a complete set of meteorological instruments, and a seismograph for determining the direction and intensity of earthquakes. The lecture-room is fitted up with folding opera-chairs and table-rests, and two lanterns for the projection on screens of spectra and of slides. The rules governing the Observatory are as simple as possible. Mondays and Tuesdays are set apart for high and grammar school pupils, Fridays for observations, and the remainder of the week for visitors and private schools. Admission is by card obtained from the school inspector, who is also the director, a happy combination which exists in another and much larger American city. The public attendance increased from 1,644 in 1886, to 2,240 in 1892, the year of re-building, since which event it has been found to be impossible to keep an accurate record, but the estimated annual attendance is not less than 5,000.

Take, from many which could be cited, another case where intelligent generosity has asserted itself to some purpose, that of the Smith Observatory, Geneva, New York, the director of which is the famous discoverer of comets, Professor W. R. Brooks. In this instance, a retired capitalist, desiring to do something for his fellows, erected, in his spacious grounds, a residence for his director, and an observatory in which he mounted a 10-inch Clark telescope, a 4-inch transit, the necessary clocks, etc. Mr. Smith's purpose in erecting the Observatory was announced to be "the increased and diffusion of astronomical knowledge." Hence, the public is welcomed every clear night, and all-comers are instructed by Mr. Brooks, who shows them fine views of celestial objects. Visitors come from Geneva itself, from the surrounding towns, and from all parts of the country, and, as Professor Brooks says in a communication to the writer of this paper, "freely express their thanks and appreciation for the rare privileges afforded them." Illustrated lectures are given to the public and to the schools.

(TO BE CONTINUED.)

SPECTROSCOPIC NOTES.

Mr. T. E. Espin publishes in *Astronomishe Nachrichten*, No. 3559, in continuation of his previous work on the subject, a list of about 70 'stars with remarkable spectra.' The present stars are in point of brightness well toward the lower limit of the Bonn Durchmusterung, and Mr. Espin remarks that the fainter stars were difficult to observe in his 17-inch mirror. Nearly all are of the third type, two or three of the fourth type, and one or two anomalous.

In response to the statements of Mr. Evershed and of Mr. Wright and Prof. Campbell that the position of the *Hδ* line of hydrogen in the Sun's spectrum as published by Prof. Rowland seemed to be in error by about 0.1 Ångstrom unit, Mr. Jewell states in the *Astrophysical Journal* for April that on account of the character of the spectrum in the neighborhood of the line the position of the line depends to a slight degree on the assumption made with regard to its intensity.

Miss Clerke in an interesting contribution to the *Observatory* for April collates some recent results of the study of the spectrum of o Ceti (Mira). In particular she points out that the bright lines of iron detected by Professor Campbell during the maximum of the star in 1898 do not appear on the photographs of the spectrum taken at Potsdam in 1896 and at Stonyhurst in 1897. As the star at these maxima was noticeably fainter than at the last maximum (about magnitude 4 in 1896, against magnitude 2.6 in 1898) it would seem that the character of the spectrum of the star at any maximum depends on the brightness of the star at that maximum.

In a short note to the *Observatory*, April, pointing out the misleading character of a statement in a previous number of the same periodical, Professor Keeler states that it is the experience of the Lick observers in their measurements of motion of nebulæ in the line of sight that the results from visual observations vary not more than 3 kilometers (2 miles) per second for different observers, and the results from photographs not more than a fraction of a km. per sec.

The *Astrophysical Journal* for April contains a discussion of the spectrum of the very rare metal, Gallium, and its presence in the Sun and in meteorites. Professors Hartley and Ramage, finding Gallium to be a constituent of a variety o minerals, were led to test for its presence in the Sun, and in their paper entitled 'A determination of the wave-lengths of the principal lines in the spectrum of Gallium, showing their identity with two lines in the solar spectrum' the evidence of the presence of Gallium in the Sun would seem to be established conclusively. In examining meteorites they found that Gallium is present in one only of the siderolites examined; but is a constituent of all the iron meteorites, in varying proportion. Dr. Jewell, commenting on these results, states that Professor Rowland, when photographing the spectra of the metals, could secure no specimen of Gallium, either the metal or a salt. On examination of the spectrum plates, the two Gallium lines were found prominently on the aluminium and lead plates, and faintly on the silver plates and some of the plates of iron. The exact coincidence of the two lines with solar lines was confirmed. Dr. Jewell's observations of some meteorites were largely confirmatory.

In editing the series of "Harper's Scientific Memoirs," which he has recently undertaken, Professor Ames does much for the diffusion of scientific information of the highest type by reprinting important original publications, otherwise inaccessible except to a few, in accurate but inexpensive and compact form. No. 2 of the series, entitled "Prismatic and Diffraction Spectra," a booklet of 68 octavo pages is particularly welcome, containing as it does a translation of some of Fraunhofer's classic and romantic work,—hitherto peculiarly inaccessible,—on the discovery of the lines of the spectrum which will always bear his name, and on the classification of the stars by their spectra.

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

1899.

U CEPHEI.

	d	h
July	1	22
	4	10
	6	22
	9	10
	11	21
	14	9
	16	21
	19	9
	21	21
	24	9
	26	20
	29	8
	31	20
Aug.	3	8
	5	20
	10	19
	15	19
	20	19
	25	18
	30	18

ALGOL.

	d	h
July	1	23
	4	19
	7	16
	24	21
	27	18
	30	15
Aug.	13	23
	16	20
	19	16
	22	13

λ TAURI.

	d	h
July	17	23
	21	22
	25	21
	29	20

λ TAURI Con't.

	d	h
Aug.	2	19
	6	18
	10	17
	14	16
	18	14
	22	13
	26	12

δ LIBRÆ.

	d	h
July	5	15
	12	14
	19	14
	26	13
Aug.	23	12
	30	11

U CORONÆ.

	d	h
July	2	19
	9	17
	16	14
	23	12
	30	10
Aug.	9	18
	16	16
	23	14
	30	11

U OPHIUCHI.

Every 10th min.

P = 20h.1

	d	h
July	2	3
	10	12
	18	21
	27	6
Aug.	4	16
	13	1
	21	10
	29	20

RS SAGITTARII.

	d	h
July	3	12
	5	22
	8	8
	10	18
	15	14
	20	10
	22	20
	27	16
Aug.	1	12
	3	22
	6	7
	8	17
	13	13
	18	9
	20	19
	25	15
	30	21

W DELPHINI.

	d	h
July	11	21
	16	16
	21	12
Aug.	4	22
	9	17
	14	13
	19	8

DM + 12°,3557

	d	h
July	1	21
	2	18
	3	15
	4	13
	5	10
	6	8
	9	21
	10	18

DM + 12°,3557

	d	h
	11	16
	12	13
	13	10
	14	8
	17	21
	18	18
	19	16
	20	13
	21	10
	22	8
	25	21
	26	19
	27	16
	28	13
	29	11
	30	8
Aug.	3	19
	4	16
	5	13
	6	11
	7	8
	11	19
	12	16
	13	14
	14	11
	15	8
	19	19
	20	16
	21	14
	22	11
	23	8
	27	19
	28	17
	29	14
	30	11
	31	9

Maxima and Minima of Long Period Variables.

1899 AUGUST.

MAXIMA.

		Mag.	Aug.
401	U Sculptoris	8.7	29
494	R Sculptoris	5.7	24
845	R Ceti	7.5	18
980	V Persei*	7.9	8
1222	R Persei	7.7	23
2690	X Puppis	8	30
2742	S Geminorum	8.2	25
3477	R Leonis minoris	6.1	18
3825	R Ursae Majoris	6.0	9
4826	R Hydrae	3.5	8
5583	X Librae	9.5	5
5601	S Ursae minoris	7.4	28
5752	RZ Scorpii	9	6
5856	W Ophiuchi	8.9	31
6170	RW Scorpii	9.4	16
6225	RS Herculis	8	25
6449	T Draconis	8.2	12
7085	RT Cygni	7.0	31

MAXIMA, Con't.

		Mag.	Aug.
7234	R Capricorni	8.8	14
7379	ST Cygni	9	1
7404	R Microscopii	8	31
7450	V Aquarii	8.1	13
7456	RR Cygni	8.1	24
7896	V Pegasi	8.2	19
7907	U Aquarii	9.5	10
7909	S Piscis Austr.	8.7	17
8597	V Ceti	8.5	31

MINIMA.

466	U Piscium	15	26
782	R Arietis	13.0	14
2946	R Cancri	< 11.7	20
3994	S Leonis	< 13	29
5887	V Ophiuchi	10.5	5
5889	U Herculis	12.7	4
7659	T Capricorni	13.5	14

SEPTEMBER.

MAXIMA.

		Mag.	Sept.
112	R Andromedae	5.6	26
267	V Andromedae	8.8	23
806	o Ceti (Mira)	1.7	2
1577	R Tauri	7.4	14
1717	V Tauri	8.3	18
2478	R Lyncis	7.8	4
2530	V Canis minoris	10.3	8
2976	V Cancri	6 8	10
3128	R Pyxidis	8	2
4471	T Canum Ven.	8 6	3
4896	T Centauri	5.9	6
4940	W Hydrae	6.7	3
5070	Z Virginis	9 5	12
5494	S Librae	7 6	15
5677	R Serpentis	5.6	9
5761	Z Scorpii	9.0	14
5776	X Scorpii	10	23

MAXIMA, Con't.

		Mag.	Sept.
5931	S Ophiuchi	8.3	28
6899	U Draconis	9 0	13
6903	T Sagittarii	7.6	22
6905	R Sagittarii	7.0	12
7139	RR Sagittarii	7 5	6
7468	T Aquarii	6.7	28
7783	RU Cygni	7.5	18
7919	X Aquarii	8 3	22
8373	S Pegasi	7.3	12

MINIMA.

4492	Y Virginis	13	23
4596	U Virginis	12 8	5
5157	S Bootis	13 2	14
5190	R Camelopard	13.5	27
6682	X Ophiuchi	9.0	18
7560	R Vulpeculae	13.6	14

The dates in the above list are taken from Dr. Hartwig's ephemeris in the *Vierteljahrsschrift* except for the Algol-type stars RS Sagittarii and DM + 12°,-3557, which were computed from Chandler's and Sawyer's elements in the *Astronomical Journal*.

As POPULAR ASTRONOMY is not published in July, the ephemeris is given in this number for two months.

BARNARD'S NEW VARIABLE IN AQUARIUS. This was discovered by Professor Barnard while measuring the position of the new planet Eros with the 40-inch Yerkes telescope. The star is SDM.—4°,5381 and its magnitude is given as 9.8 by Schönfeld. In *Astronomical Journal*, No. 456, Professor Barnard gives details of the discovery and photographic magnitudes determined at the Harvard College Observatory since 1890.

* Note to V Persei, in the Long Period list. This star is called W Persei in Hartwig's list.

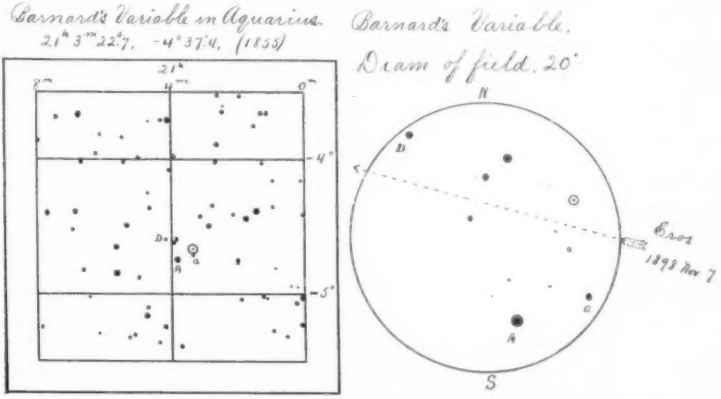
The position is

R. A. $21^h\ 3^m\ 22^s.7$, Dec. $-4°\ 37'.4$, (1855)
$5\ \ 43\ .1$ $\ \ 26\ .6$, (1900)

The square chart, on the scale of the SDM, gives the stars from 8^m to 10^m within 1° of the variable. Examples of Schönfeld's magnitudes are

A	$8^m.0$
D	9 .3
a	9 .7

The circular chart on a larger scale gives the field including these three stars and the variable, with such of the neighboring stars as are needed for identification, down to about 13^m. On this chart the arrow shows the path of Eros across the field 1898 Nov. 7, when its daily motion was just about the diameter of the field. This path is located by means of Berberich's ephemeris in No. 3520 of the *Nachrichten*, including Cerulli's correction given in No. 3527.



Professor Barnard found the variable about 12^m 1898 Nov. 7, after which it increased to $9^m.7$ by Dec. 8, his last evening observation. I followed it in the evening sky till 1899, Jan. 14, finding a further increase of three or four-tenths of a magnitude. So far it has been too faint to be seen in the morning sky, my observed dates and limits being

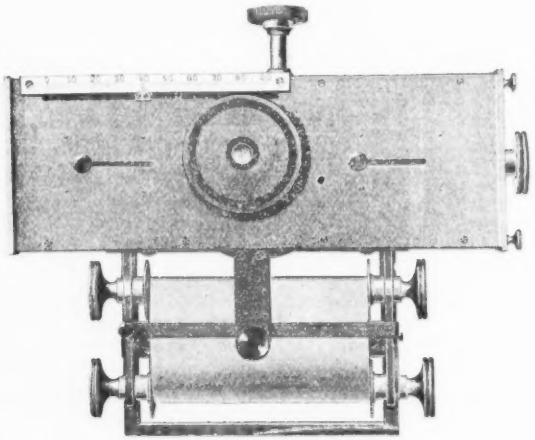
1899 Mar. 22, $< 9^m.6$
Apr. 4, $< 10\ .6$
16, $< 11\ .6$
21, $< 11\ .8$

Probably it will soon be visible, as the photographic observations indicate a period of about 150 days.

NEW OBSERVATORY IN ALTENBURG, GERMANY. Dr. Friedrich Krüger, the Director, has lately issued a pamphlet describing the equipment and work of this Observatory, with illustrations of the buildings and instruments. As part of the work will be the photometric observation of variables and their comparison stars, the instrument which he will use, a wedge photometer, will be of interest in this connection. It consists essentially of a thin wedge of neutral tinted glass, 70^{mm} long, movable across the field of view by a pinion whose head is

shown above the middle of the box. The light of the star is determined by the thickness of the wedge which it can penetrate, and the measurement consists in noting the position of the wedge just as the star is extinguished. This position can be read by the pointer which slides along the millimeter scale shown at the top of the box, or recorded by the registering device under the box. The arm shown is connected with the wedge frame and slides back and forth with it, carrying a sharp point by which a puncture can be made on the roll of paper which passes over the pair of cylinders. After a series of observations the paper is unrolled from the cylinders and the distances of the punctures from the left-hand edge of the paper, are read off by the aid of a millimeter scale, thus giving the position of the wedge at the corresponding observations. The buttons on each side of the ocular at the end of a slot, served to move in or out of the field of view a plate of metal with a small slit opening in which the image of the star is kept, thus making sure that the scale readings are not vitiated by accidental movements of the star image.

The wedge photometer is the simplest instrument for measuring magnitudes. The accuracy attainable with it is shown by the excellence of Professor Pritchard's photometric catalogue, the "Uranometria Nova Oxoniensis." The wedge can be calibrated by observations of standard stars whose magnitudes are known. There are two disadvantages attending its use. First, the work is very trying to the eye from the effort of determining the point of extinction of the star image. Second, the wedge cuts down the illumination of the field by sky light, and cuts it down in a different degree for stars of different magnitude, as the observations are made at different points on the wedge. Thus a correction is required the amount of which it is not easy to determine with accuracy.



The photometer shown in the cut was made by Hans Heele in Berlin.

U GEMINORUM. It is again a coincidence that the two stars of this type are bright at the same time. SS Cygni is passing a maximum at this writing (a fuller report will be given later) while the maximum of U Geminorum evidently happened about May 5.0, as the following few observations will show—

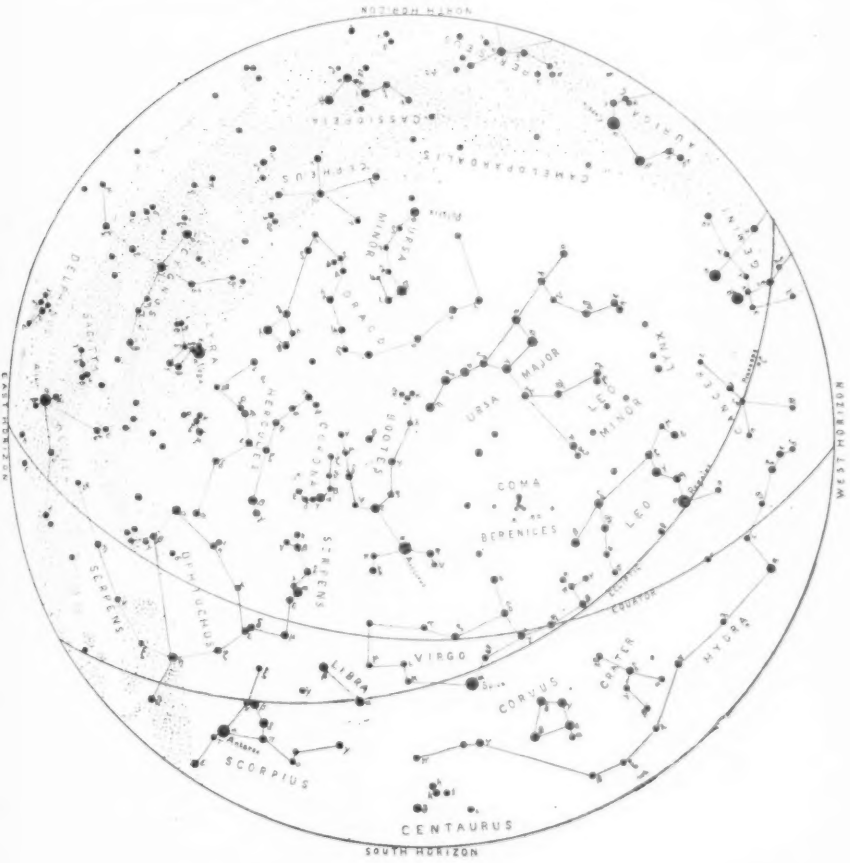
1899 May 1.63	13m.8	P	May 6.58	9.9	P
4.63	10 .45	D	8.62	10.7	P

In the column headed "Obs." D stands for Zaccheus Daniel and P. for J. A. Parkhurst.

PLANET NOTES FOR JUNE.

H. C. WILSON.

Mercury will be at superior conjunction June 14 and so will not be visible to the naked eye during the month. In July Mercury will reach greatest eastern elongation on the 22d and will be visible in the evening at that time.



THE CONSTELLATIONS AT 9 P. M., JUNE 1, 1899.

Venus is "morning star", easily seen toward the east in the morning, but far less conspicuous than in the early months of the year. The brightness of the planet decreases in the ratio of 59 to 52 during the month.

Mars is "evening star", passing through the constellation Leo, seen toward the west in the early evening during June and July. The planet will be in conjunction with the first magnitude star Regulus, less than a degree north of the star on June 12. The contrast between the ruddy color of the planet and the bluish white of the star will readily distinguish the planet from the star.

Jupiter is a glorious object these evenings and the visitors at our observatory recently have enjoyed a number of splendid views of the planet. The Great Red Spot is scarcely visible but the great notch in the southern temperate belt shows its location plainly. Jupiter is making the turn of the western end of the loop in Virgo (See chart in January 1899 No. of POPULAR ASTRONOMY p 39); will be stationary June 27, and after that time will move southeastward. Jupiter will be at quadrature July 24.

Saturn will be at opposition June 11, and is to be seen best about midnight. This planet will be in its best position for observation during the summer months and is easily distinguished from the stars by its golden hue and steady light. It is to be found in the foot of Ophiuchus, between the conspicuous constellations Scorpio and Sagittarius. So far as reported to us, no one has as yet been able to see the new satellite of Saturn, which was discovered by Professor Pickering upon the photographs taken at Arequipa, Peru. We hope to be informed soon that a visual observation has been obtained.

Uranus is in best position for the year and may be observed about 11 P. M. in Scorpio, between three and four degrees southeast of the star β, and five degrees north and a little west of the star α (Antares).

Neptune is behind the Sun, reaching superior conjunction June 14.

The Moon.

	Phases.	Rises. (Central Standard time at Northfield; Local Time 13m less.)	Sets. (Central Standard time at Northfield; Local Time 13m less.)
		h m	h m
June 8	New Moon	4 35 A. M.	8 37 P. M.
16	First Quarter	12 42 P. M.	12 14 A. M.
23	Full Moon	8 22 P. M.	5 35 "
29	Last Quarter	11 31 P. M.	1 15 P. M.

Occultations Visible at Washington.

Date 1899.	Star's Name.	Magnitude.	IMMERSION. Washington M. T.	IMMERSION. Angle f'm N pt.	EMERSION. Washington M. T.	EMERSION. Angle f'm N pt.	Duration.
			h m	°	h m	°	h m
June 3	104 Piscium	7.5	14 2	109	14 42	205	0 40
21	18 Ophiuchi	6.7	14 8	53	15 4	296	0 56
23	ν^1 Sagittarii	5.0	11 25	86	12 43	247	1 18
23	ν^2 Sagittarii	5.1	11 57	82	13 16	249	1 19
23	*o* Sagittarii	3.8	17 8	47	18 1	274	0 53
28	16 Piscium	5.8	10 8	89	10 57	224	0 49
28	19 Piscium	4.9	15 37	83	16 46	207	1 9

Jupiter's Satellites for June.

Central Standard Time.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I.

III.

II.

IV. No Eclipse.

Configurations at 9 h 30 m for an Inverting Telescope.

Day.	West.	East.
1	·2 ·1 ○	·3 4·
2	○ 1· ·2 3· 4·	
3	·1 ○ 3·2· 4·	
4	3·2· 4· ○1·	
5	·3 4· ○	·2● ·1●
6	·4 ·3 1· ○ 2·	
7	4· 2· ○ ·3 ·1	
8	·4 ·2 1· ○ ·3	
9	·4 ○ 1· ·2 3·	
10	·4 ·1 ○ 3·2·	
11	·4 2· 3· ○ 1·	
12	3· ·4 ○	·2● ·1●
13	3· 1· ○ ·4 2·	
14	2· ○ ·3 ·1 ·4	
15	·2 1· ○ ·3 ·4	
16	○ ·1·2 3· ·4	
17	·1 ○ 2· 3· 4·	
18	2· 3· ○ 1· 4·	
19	3· ·2 ·1 ○ 4·	
20	○1 ·3 ○ 4· ·2	
21	4· 2. ○ ·1	·3●
22	4· ·2 1· ○ ·3	
23	4· ○ ·2 ·1 3·	
24	4· ·1 ○ 2· 3·	
25	·4 2· 3· ○ 1·	
26	·4 3· ·2 ·1 ○	
27	·4 ·3 ○1· ·2	
28	○2· ·4 ·3 ○	·1●
29	·2 1· ○ ·4 ·3	
30	○ ·2 ·1 ·4 3·	

Phenomena of Jupiter's Satellites.

Central Standard Time.

	h	m				h	m			
June 4	12	44	A. M.	II	Tr. In.	June 14	12	0	Midn.	III	Ec. Re.
	12	52	A. M.	III	Tr. In.	19	11	1	P. M.	I	Oc. Dis.
	12	57	"	I	Oc. Dis.	20	12	13	A. M.	II	Oc. Dis.
	10	11	P. M.	I	Tr. In.		8	16	P. M.	I	Tr. In.
	11	3	"	I	Sh. In.		9	22	P. M.	I	Sh. In.
5	12	23	A. M.	I	Tr. Eg.		10	29	"	I	Tr. Eg.
	1	15	"	I	Sh. Eg.		11	34	"	I	Sh. Eg.
	7	24	P. M.	II	Oc. Dis.	21	8	44	P. M.	I	Ec. Re.
	7	24	"	I	Oc. Dis.		8	53	"	II	Sh. In.
	10	26	P. M.	I	Ec. Re.		8	58	"	II	Tr. Eg.
	11	29	"	II	Ec. Re.		9	49	"	III	Oc. Dis.
6	7	44	"	I	Sh. Eg.		11	13	"	II	Sh. Eg.
11	12	0	Midn.	I	Tr. In.		11	42	"	III	Oc. Re.
12	12	59	A. M.	I	Sh. In.	27	10	8	P. M.	I	Tr. In.
	9	12	P. M.	I	Oc. Dis.		11	17	"	I	Sh. In.
	9	48	"	II	Oc. Dis.	28	12	21	A. M.	I	Tr. Eg.
13	12	13	A. M.	I	Ec. Re.		7	18	P. M.	I	Oc. Dis.
	7	27	P. M.	I	Sh. In.		9	4	"	II	Tr. In.
	8	39	"	I	Tr. Eg.		10	38	"	I	Ec. Re.
	9	39	"	I	Sh. Eg.		11	25	"	II	Tr. Eg.
14	8	3	"	III	Oc. Re.		11	28	"	II	Sh. Eg.
	8	39	"	II	Sh. Eg.	29	7	58	"	I	Sh. Eg.
	10	31	"	III	Ec. Dis.	30	8	39	P. M.	II	Ec. Re.

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of satellite; Sh., transit of shadow.

COMET NOTES.

H. C. WILSON.

Ephemeris of Comet 1899 *a* (Swift).

1899	α app. h	m	s	δ app. °	′	″	log *r*	log Δ	Br.
June 1	17	58	35	+ 56	13	.1			
2		56	8	55	13	.8	0.0994	9.7520	1.34
3	17	15	28	54	1	.7			
4	16	56	46	52	39	.2	0.1120	9.7667	1.18
5		39	54	51	9	.5			
6		24	46	49	34	.6	0.1242	9.7857	1.03
7	16	11	13	47	57	.1			
8	15	59	12	46	18	.1	0.1360	9.8077	0.88
9		48	32	44	39	.5			
10		39	2	43	2	.2	0.1473	9.8320	0.75
11		30	32	41	27	.2			
12		22	56	39	54	.7	0.1582	9.8576	0.63
13		16	5	38	25	.4			
14		9	57	36	59	.3	0.1688	9.8838	0.53
15	15	4	27	35	36	.6			
16	14	59	29	34	17	.3	0.1791	9.9102	0.45
17		54	57	33	1	.3			
18		50	51	31	48	.7	0.1890	9.9365	0.38
19		47	7	30	39	.7			
20	14	43	45	+ 29	33	.4	0.1986	9.9622	0.32

Ephemeris of Tuttle's Comet *b* 1899.

1899		α app. h m s		δ app. ° ′ ″			log Δ	Ab.-Zeit m s		H
June	1	6	31	16.9	− 4	9	14	0.23284	14	10.9	1.64
	2		34	41.6	4	40	27				
	3		38	6.7	5	11	39				
	4		41	32.3	5	42	49				
	5		44	58.4	6	13	58	0.23342	14	12.1	1.57
	6		48	25.0	6	45	5				
	7		51	52.1	7	16	9				
	8		55	19.7	7	47	11				
	9	6	58	47.9	8	18	9	0.23440	14	14.0	1.49
	10	7	2	16.7	8	49	4				
	11		5	46.1	9	19	55				
	12		9	16.1	9	50	41				
	13		12	46.6	10	21	23	0.23590	14	16.9	1.41
	14		16	17.7	10	51	59				
	15		19	49.5	11	22	29				
	16		23	21.8	11	52	53				
	17		26	54.8	12	23	10	0.23796	14	21.0	1.32
	18		30	28.3	12	53	20				
	19		34	2.5	13	23	22				
	20		37	37.2	13	53	15				
	21		41	12.6	14	23	0	0.24066	14	26.4	1.24
	22	7	44	48.6	14	52	35				
	23	7	47	25.2	15	22	1				
	24		51	32.4	15	51	16				
	25		55	40.2	16	20	21	0.24402	14	33.1	1.16
	26	7	59	18.7	16	49	14				
	27	8	2	57.7	17	17	56				
	28		6	37.3	17	46	26				
	29		10	17.4	18	14	43	0.24811	14	41.4	1.08
	30	8	13	58.1	− 18	42	48				

Ephemeris of Holmes' Comet

[From *Astronomische Nachrichten*, No. 3553.]

		R. A. h m s	Decl. ° ′ ″	Br.
June	1	0 59 4.4	+ 14 31 58	0.032
	3	1 2 28.9	15 8 43	
	5	5 52.7	15 45 23	0.032
	7	9 15.6	16 21 58	
	9	12 37.7	16 58 27	0.033
	11	15 58.8	17 34 51	
	13	19 19.0	18 11 8	0.034
	15	22 38.3	18 47 18	
	17	25 56.5	19 23 22	0.034
	19	29 13.8	19 59 19	
	21	32 29.9	20 35 8	0.035
	23	35 44.9	21 10 50	
	25	38 58.8	21 46 25	0.036
	27	42 11.4	22 21 51	
	29	45 22.7	22 57 10	0.037
July	1	1 48 32.7	+ 23 32 21	

Comet Tempel 1873 II.—This comet was picked up by Perrine at Lick Observatory on the morning of May 7 very close to the ephemeris place as calculated by Schulhof, the error being only about 2′ of arc. We continue the ephemeris since it is sufficiently accurate to enable observers to follow the comet.

EPHEMERIS OF COMET TEMPEL2 1873 II.

[From *Astronomische Nachrichten* No. 3554.]

	R. A.			Decl.			log Δ	Br.
	h	m	s	°	′	″		
June 1	19	34	17.4	− 3	52	50	9 79502	1.121
2		35	48.4	3	55	17	9.78933	
3		37	19.0	3	58	10	9.78364	
4		38	49.0	4	1	30	9.77797	
5		40	18.6	4	5	17	9.77230	1.271
6		41	47.6	4	9	34	9.76664	
7		43	16.1	4	14	21	9.76100	
8		44	44.2	4	19	38	9.75537	
9		46	11.7	4	25	27	9.74976	1.439
10		47	38.8	4	31	49	9.74417	
11		49	5.4	4	38	45	9.73860	
12		50	31.5	4	46	16	9.73306	
13		51	57.2	4	54	22	9.72755	1.625
14		53	22.4	5	3	5	9.72207	
15		54	47.2	5	12	25	9.71662	
16		56	11.5	5	22	24	9.71121	
17		57	35.4	5	33	2	9.70585	1.829
18	19	58	58.9	5	44	20	9.70053	
19	20	0	21.9	5	56	19	9.69525	
20		1	44.5	6	8	59	9.69002	
21		3	6.7	6	22	21	9.68484	2.048
22		4	28.5	6	36	27	9.67972	
23		5	49.8	6	51	16	9.67466	
24		7	10.7	7	6	49	9.66966	
25	20	8	31.1	− 7	23	7	9.66473	2.281

Ephemeris of Comet 1898 VIII.

1899	True α			True δ			log Δ	Br.
	h	m	s	°	′	″		
June 2	11	8	41.18	+ 29	52	11.5	0.5495	0.17
4		10	15.27	29	33	34.0	5544	
6		11	51.22	29	14	53.2	5593	0.16
8		13	28.95	28	56	9.8	5641	
10		15	8.38	28	37	24.4	5688	0.15
12		16	49.44	28	18	37.8	5735	
14		18	32.00	27	59	50.0	5782	0.14
16		20	15.97	27	41	1.3	5828	
18		22	1.30	27	22	12.4	5873	0.13
20		23	47.95	27	3	24.3	5918	
22		25	35.83	26	44	37.0	5962	0.12
24		27	24.85	26	25	50.5	6005	
26	11	29	14.97	+ 26	7	5.6	0.6048	0.12

GENERAL NOTES.

For the last three years, this magazine has been issued every month without a change in the size of the volumes, only a change in the date of the beginning of each during that period. The object of this was to bring the date of the beginning of the volumes to come later, at the beginning of the calendar year. This was accomplished in January 1899. Hereafter only ten numbers will be issued during each calendar year. No numbers will appear for the months of July or September of this year. The next will be published for August.

We have given place elsewhere in this number to parts of two strong articles, because of their practical value. The function of criticism in the Advancement of Science by Professor F. H. Bigelow is an article that every lover of science may read with profit as a useful historical review, as well for the broad range of suggestion as for the actual facts cited. But more than this the author has done nobly in setting forth clearly the real meaning and uses of criticism properly so called.

Popular readers and amateurs will certainly read the article by George E. Lumsden on a Popular Astronomical Observatory with unusual interest. It answers well many common questions, about observatories, instruments, things to do and things to learn that astronomers are expected to answer over and over again quite constantly. The article contains an excellent summary of useful information.

A Remarkable Aurora.—On the evening of May 3, 1899, at 10:20 a brilliant aurora was observed at this point, showing some remarkable features. It consisted of a belt of light about five degrees wide, passing from west northwest to east southeast. Beginning at a point about 20 degrees above the horizon in the constellation of Gemini, it passed through the zenith near the constellation Coma Berenices, passed across Corona borealis and terminated at a point about 20 degrees from the horizon. Nearly the entire belt consisted of rays or streamers rapidly moving in the direction of the belt from E. S. E. to W. N. W. The rays were all directed toward a point in Coma Berenices. The entire belt moved southward, and twenty minutes after the time of its first observation had shifted its position about fifteen degrees, passing the radiant in Coma Berenices, although the rays were still directed toward that point.

WEST SUPERIOR STATE NORMAL SCHOOL. N. A. HARVEY.

The Moon's Secular Acceleration.—In looking for the cause of the secular acceleration of the Moon's motion it seems to me that it would be well to investigate the effect which a gradual decrease in the mean angle between the Moon's orbit and equator would have on her orbital motion.

It is a well known fact that on account of the secular change in the obliquity of the ecliptic the angle between it and the equator has for a long time been gradually diminishing, so that this angle is now about 24′ less than it was 2,000 years ago.

It is easily seen also that as a necessary consequence the *mean* angle between the Moon's orbit and the equator has also decreased by a like amount in the same time and is still decreasing at the same rate. This comes from the fact that, on account of the revolution of the Moon's nodes, the angle between her orbit and the equator, although constantly varying must nevertheless always be the same on an *average*, as the angle between the ecliptic and the equator; any decrease therefore in the latter angle must necessarily cause a like decrease in the former.

Now, of course, in the case of a perfectly *spherical* planet, the force of attraction on a satellite revolving around it would be the same, no matter what the inclination of its orbit to the equator might be, but it can be easily demonstrated that the attraction of an *oblate* planet such as the Earth is known to be is necessarily a little greater on a satellite revolving around it in the plane of its equator than it is on one revolving around it in an orbit of the same dimensions but inclined to this plane.

The Earth's attraction is certainly a little greater on the Moon when she is over the *equator* than it would be on her at the same *distance* from the *center* of the *Earth* but directly over one of the *poles*. It follows that the Moon would necessarily move a little *faster* in an orbit directly in the plane of the equator than she would move in an orbit of the same dimensions at right angles to the equator.

Now as the secular change in the obliquity of the ecliptic is gradually diminishing the *mean* angle between the Moon's orbit and the equator, it seems to me that the resulting increase in the force of the Earth's attraction on her would *necessarily* bring about a slight acceleration in her orbit motion. Of course a decrease in this angle of only about 24′ in 2000 years would not cause enough difference in the force of the Earth's attraction on her account in this way *alone* for the *entire* acceleration observed, but it must be borne in mind that a *part* of this acceleration is caused, as La Place long ago proved, by the gradual decrease in the eccentricity of the Earth's orbit, leaving only a *part* of it to be accounted for in this way by the gradual decrease in the *mean* angle between the Moon's orbit and the equator.

ISAAC E. CHRISTIAN.

OCEANA, W. Va.

A Total Eclipse of the Moon will occur on June 23. It will not be visible in the United States, except in the very western part, where the beginning will be noticed before the Moon sets in the morning of the 23rd. It will be visible generally throughout the Pacific Ocean and the continent of Asia, and the end will be seen in the eastern part of Africa.

TIMES OF THE PHASES.

		Greenwich M. T.		Central Standard Time.		
		h	m	h	m	
Moon enters penumbra	June 22	23	36.4	5	36.4	A. M.
Moon enters shadow	23	0	32.9	6	32.9	"
Total eclipse begins		1	32.8	7	32.8	"
Middle of the eclipse		2	17.9	8	17.9	"
Total eclipse ends		3	2.9	9	2.9	"
Moon leaves shadow		4	2.7	10	2.7	"
Moon leaves penumbra		4	59.5	10	59.5	"

Magnitude of the eclipse = 1.488 (Moon's diameter = 1.0)

A Partial Eclipse of the Sun will take place June 7 the morning of June 8, civil time, but will be invisible in the United States. It will be seen in northern Europe, northern Asia, Alaska, Greenland and the region about the North Pole. In England the eclipse will begin soon after sunrise on the 8th and end at about 6^h A. M.

Editor of POPULAR ASTRONOMY, Dear Sir:—Professor See has called my attention to an erroneous statement inadvertently made in my article on Lane's Law, etc., to the effect that Professor Peirce had "*published* two or three papers on the subject in the Proceedings of the American Academy (Boston)." On reference to Vol. XII of the Proceedings (which was not at hand when I wrote) I find that the communications were *presented* at the meetings of March 14 and April 11, 1877, very likely orally; and I find no evidence that they were ever printed.

C. A. YOUNG.

The Solar Cyclones.—The accompanying illustration represents the change of position noticed in the cyclonic sunspot described on page 278 of POPULAR ASTRONOMY for May. It crossed the disk between March 25th and April 8th and though not much beyond the average size, the tendency to vertical motion was a feature of unusual interest.

A group of spots, observable here only on a few days, owing to cloudiness, were on the disk towards the latter part of March, and an interesting account of rapid changes within them has appeared in *The Observatory* for May. The prodigious velocity of the movements in this case, though indicating unwonted violence in a comparatively small solar storm, is scarcely an evidence of the vortical motion demanded by the theory of M. Faye, which would be the slower effect produced by different rates of rotation in photospheric zones adjacent to the group.

SUNSPOT.

March 29th. April 1st. April 4th.

The spot illustrated, which appeared on the disk some days later, changed the direction of its ellipticity but a few degrees from day to day, and otherwise had little instability of form or irregularity of outline except what was caused by the effects of foreshortening. It came into view again by rotation on April 23d, but in transit, gave no evidence of cyclonic motion, though several small spots appeared and disappeared in its neighborhood.

Observers who have appliances for solar photography, and facilities for very accurate measurement, are probably in possession of some valuable details as to the Sun's surface during those weeks, and spectroscopic observation during that period will also be of much interest when forthcoming. ROSE O'HALLORAN.

SAN FRANCISCO, May 19, 1899.

Photographic Plates and the Eye.—Professor J. Scheiner writes in the *Archiv fur Wissenschaftliche Photographie* concerning the application of photographic methods to the exact sciences, and especially to astronomy. In making a comparison between the eye and the dry plate, Professor Scheiner points out that it is the accumulation of the effect of light which gives the plate the advantage. If we look through a telescope of three inches' aperture, and the eye is not fatigued, stars down to the twelfth magnitude may be distinguished, and for this purpose the observation need not exceed ten to twenty seconds. A plate exposed for the same time under similar conditions would only record stars down to the sixth magnitude, and we might infer that the eye is 250 times more sensitive than the plate. From experience we know that an exposure of an hour has to be given to a dry plate with the same telescope, if we wish to obtain a record of the stars we can distinguish with the eye. If we give still longer exposures, the advantage lies with the plate; and, as astronomical exposures have

been made of twenty-five hours' duration, it will be readily understood how great is the service photography renders to the astronomer.—*The British Journal of Photography.*

The Rotation of Jupiter.—Mr. W. F. Hopkinson, of Williamsport, Pa. sends us the following ephemeris of Jupiter's rotation, in which he places the prime meridian so that it passes through the "cliff" at the eastern end of the notch in the south tropical belt which now locates the position of the "Great Red Spot." The times given are for Eastern Standard Time.

		Longitude at 8 P. M.	Prime Meridian Central.			Longitude at 8 P. M.	Prime Meridian Central.
		°	h m			°	h m
June	1	24	7 20 P. M.	June	23	91	5 29 P. M.
	2	174	.....		24	241	11 17 "
	3	325	8 58 "		25	31	7 9 "
	4	115	.....		26	182	.....
	5	265	10 37 "		27	332	8 46 "
	6	56	6 27 "		28	122	.....
	7	206	.....		29	272	10 26 "
	8	356	7 53 "		30	63	6 16 "
	9	146	.....	July	1	213	.....
	10	297	9 44 "		2	3	7 55 "
	11	87	5 36 "		3	154	.....
	12	237	11 24 "		4	304	9 32 "
	13	28	7 14 "		5	94	.....
	14	178	.....		6	244	.....
	15	328	8 53 "		7	35	7 2 "
	16	119	.....		8	185	.....
	17	269	10 31 "		9	335	8 41 "
	18	59	6 23 "		10	126	.....
	19	209	.....		11	276	10 19 "
	20	0	8 00 "		12	66	6 11 "
	21	150	.....		13	217	.....
	22	300	9 39 "				

Royal Observatory, Greenwich, England.—We have been favored by the Astronomer Royal, W. H. M. Christie, Greenwich Observatory, with five copies of Astronomical and Meterological results of that great Observatory obtained during the years 1896 and 1897.

A Large Meteor.—It is reported that a meteor weighing twelve pounds fell in the town of Holmesville, Minn., a few days ago, and that it is in the possession of one O. S. Parmenter of that place. The meteor is said to have struck the earth with great force burying itself in hard clay to the depth of nearly two feet. Though we have made inquiries concerning this meteor, we are, so far, unable to verify this report which appeared in local newspapers recently.

Observing Meteors from a Balloon.—In an address delivered before the Astronomical and Physical Society of Toronto, Jan. 25, 1899, by Mr. Arthur Harvey, F. R. S. C., occurs an interesting paragraph concerning an attempt to observe the Leonid meteors from a balloon, no account of which has been seen elsewhere. "In most parts of the world only a few Leonids were noted, but one observation deserves especial record as showing the devotion of astronomers to their science, and the importance now attached to meteoric astronomy. Lest the

weather should balk the observers at Meudon (Paris), a balloon was provided for their use by the Aeronautical Society of France. Balloons are now measured by their cubic contents, just as ships are measured by tonnage, and this one was of 1,200 cubic metres, which equals 130,000 cubic feet. A Mr. Cobalzar was told off to take charge of the ascent, and when it was known that the heavens at Paris and vicinity would be overcast, Messrs. Dumontet and Hansky took their place in the car. They started at 2 A. M. on the 13th. The balloon had only risen 500 feet when it shot into a beautifully clear sky. Mr. Hansky devoted himself to observing Leo, the others to the heavens at large. From 2.45 to 4.30 Mr. Hansky registered fourteen meteors, of which thirteen were in the region of the radiant. The other observers saw ten to twelve Leonids and about as many sporadic meteors. At dawn the aeronauts descended in a forest, and, some damage having been done to the balloon, involving loss of gas, they were debarred from repeating the observations the next day, which is regrettable as, judging from the observations at Lyons, they might have seen a fine display. There, on the night between the 13th and 14th, there were two observers, the first being on duty from 8 to 12.15, the second from that time until dawn. Mr. Luizet saw three Leonids shoot up before the radiant rose above the horizon at 10.30. After that he noted thirty-one meteors, of which nineteen were Leonids, and the others chiefly Geminids or Perseids. Mr. Guillaume in the three morning hours saw a hundred and thirty-four, which he thought were only two-thirds of the number that fell. They were generally orange yellow, and left a trail. Those without a trail were bluish and belonged to other swarms. Mr. de Fonvielle and Mr. Janssen, who are in control of the Aeronautical Society of France, state that three balloons will be used this year for observations of the Leonids—one in Europe, one in America, and one in Central Siberia. They will be made to hold 50,000 to 60,000 feet of gas, and observers will be able to reach an altitude of 10,000 feet. Each party will make an ascent on the 13th, two will repeat it on the 14th and the other on the 15th."

BOOK NOTICES.

Harper's Scientific Series.—We are in receipt of two more memoirs in the Harper Scientific Series edited by Professor J. S. Ames. Numbers one and two of the series on The Free Expansion of Gases, and Prismatic and Diffraction Spectra have already been noticed in POPULAR ASTRONOMY for December, 1898.

The third book in the series is by Dr. George F. Barker, Professor of Physics in the University of Pennsylvania on Röntgen rays, familiarly called X-rays, which were first observed by Professor W. C. Röntgen, of the University of Würtzburg, in 1895, and the announcement of the discovery was made in a paper appearing the same year which is re-printed in this volume as its first article. A year later another paper was written by the discover setting forth new phenomena, and later still more observations bringing out other properties which were published in 1897. Although these peculiar radiations were first detected probably by Professor Lenard, Professor Röntgen was the first to make a systematic study of their production and properties. The experiments which have given most important conclusions were made by Professor J. J. Thompson, of Cambridge, which bear on the connection of matter and electricity. The main point of inquiry has been concerning the character of the vibrations of the X-rays. Are they longitudinal vibrations in the ether, or are they transverse,

like light waves. Possibly the phenomena that we now speak of as due to properties are not *waves* at all, but simply pulses of ether whatever that may mean. This idea gives a new starting point for investigation which Professors Stokes, Thompson, Lehmann and others have been earnestly pursuing recently. Articles by Professors Stokes and Thompson also find place in this volume. The biographical sketches of the last two named scientists with bibliography pertaining to the theme and index completes this valuable little book.

The Modern Theory of Solution is the fourth memoir in the Harper Series which has been received. It is edited by H. C. Jones, Associate in Physical Chemistry in Johns Hopkins University. It will receive full notice in our next issue.

Eclectic School Readings is the name of a most admirable Series of books published by the American Book Company of New York, Cincinnati and Chicago. The volumne now before us bears the title of "The Story of the English" by H. A. Guerber. It has 338 pages, in one hundred and eleven divisions with special titles from the early times of the Druids to the present. It is a story well selected in matter and charmingly told throughout. It is well illustrated with wood cuts generally, which print better on fine book paper than even the fine half-tone cuts do ordinarily. The four colored maps add value to the book. We have been so interested in this little volumne as to read it all carefully and reread some parts of it. Such good books ought to be in every school library and every family that desires to provide best books for the young.

Algebra for Schools.—This is the title of a new book prepared by George W. Evans, instructor in mathematics in the English High School, Boston, Mass. Its publishers are Messrs. Henry Holt and Company, of New York. Its size, 12 mo. 433 pp. and cost, $1.12.

Any teacher of mathematics, at all acquainted with the books now published in most of its branches, must thoughtfully ask himself about the old adage concerning the making of many books, whether it is not already more than fulfilled. Still he knows that the arts of teaching and book-making are interdependent, and that teachers are now writing books more than formerly. Almost every new book prepared for school uses has in it some things that have seemed enough important to those who know them to call for the publication of a book to set them forth. This new work on the elements of Algebra will illustrate what we mean. The author believes that to make the work of the teacher effective, practical problems should be the means through which successive steps are to be taken to show the pupil the need of the study, its rational basis and its economy. So he has made a careful classification of problems, putting emphasis on several types of equations arising from them.

He next insists on a specific order in the reduction of the equations making the methods employed largely prominent, going so far as to require models of reasoning in every step of progress. This is a noble point and the author makes it well. If Algebra is worth anything as a means of discipline its value lies in the fact of logical processes which may be studied and used as such. Other strong features of this new book are the treatment of the literal equation, the method of solving the quadratic, treatment of variation and logarithms. The way the author handles the solution of the quadratic is now most used in the higher mathematics, and it is now adopted by the teachers in the elemental

classes of Algebra in Carleton College. This book is so useful in these important things that it ought to receive general favor.

A Popular Handbook and Atlas of Astronomy by William Peck—Some time ago a reader of this magazine asked information concerning the above named book. Replying to that query, we would say, the publishers of that work are Messrs. G. P. Putnam's Sons, 27 and 29 West 23d street, N. Y. The work is designed as a guide to knowledge of the heavenly bodies, and as an aid to those possessing telescopes. It contains 44 large plates, and numerous illustrations and diagrams. Its price is $5.50 net. It is possible that the book sought is not the one named above, but rather that known as Wm. Peck's Constellations which is a thin book and probably less expensive. This book can be obtained from Messrs. Silver, Burdett & Company, of Boston, if we are rightly informed.

Stars and Telescopes.—By David P. Todd. Published by Little, Brown & Company, Boston.

In his latest work, entitled "Stars and Telescopes," Professor David P. Todd has furnished readers of astronomy with a handbook founded on the ninth edition of Lynn's Celestial Motions. It contains a plain, unvarnished up-to-date statement of the history of astronomy, from the days of Galileo, Kepler, Newton and Laplace, to the advances and discoveries which astronomers have made during the nineteenth century. The author of "Stars and Telescopes" not only describes their work, but the tools with which they accomplished their work, such as telescopes, spectroscopes, photometers, as well as the many adaptations of the photographic camera which have revolutionized nearly all departments of this science, and afforded a welcome service in its behalf. A description is also given of the buildings wherein telescopes find their home, as, for instance, the Lick Observatory, with its 36 inch telescope; the Yerkes Observatory, containing the 40-inch telescope; the Bruce 24-inch photographic telescope, as mounted at Arequipa, Peru, in 1898. Greatly adding to the interest of the book is the account given of the makers of the telescopes, the list including the world-renowned Alvan Clark and his two sons, Alvan Graham and George Bassett. "Five times were the Clarks called upon to construct a telescope more powerful than any now in existence, and each time the advance was from one to six inches in excess of the aperture of the then greatest glass." Among others, the excellent work of Sir Howard Grubb is referred to, concerning the 27-inch telescope mounted at the Imperial Observatory, Vienna; Brashear's star-spectroscope, which is attached to the eye-end of the 36-inch Lick telescope; the equatorial coudé, designed by Loewy; and the marked success of Warner and Swasey, of Cleveland, Saegmuller and others in their construction of mountings for smaller instruments, until one fully appreciates the importance of the mechanician and optician in furthering original research in physics and astronomy.

The first few chapters of the book contain an outline of astronomical discovery, a brief account of the Earth and Moon, and the Calendar. A chapter on the astronomical relations of light is intended to emphasize the importance of this phenomenon in all celestial inquiry. The Sun, its surface, light, heat are next set forth, and that most impressive of all natural phenomena, total eclipses of the Sun. The solar system, planets, comets and meteors, with special reference to the great meteoric showers of 1899 and 1900 next claim their share of attention, while the final chapters are about the constellations, cosmogony, the fixed stars and nebulae, the latter chapter being of special interest, due to the

methods of the new astronomy which have achieved such marvelous success in searching the star-depths. At the end of each chapter has been added a bibliographic note, for those who wish to consult authorities on the subjects discussed in the preceding chapter. The book is profusely illustrated throughout, a special feature being the portraits of a large number of well-known astronomers. The book is undoubtedly a welcome addition to the list of works on popular astronomy and being a most entertaining and *readable volume.*

MARY PROCTOR.

An illustrative paragraph from Professor Todd's new book is given below:

The Planet Eros.—"Planet (433) Eros possesses exceptional interest because of the large eccentricity of its orbit, and its mean distance is only 1.46, that of Mars being 1.52. But it is not proper to describe the path of Eros as lying within that of Mars, because the perihelion points of the two orbits lie on opposite sides of the Sun. Only about half of Eros' path, therefore, is within that of Mars: but so eccentric is the orbit that it approaches within 14 millions of miles of our own path around the Sun. When Eros comes to opposition near the time of perihelion, as must have been the case in 1894, its stellar magnitude is about the 7th, or almost within naked-eye visibility. Professor Pickering and Mrs. Fleming have re-discovered the planet on about 20 Harvard plates exposed near this time, greatly enhancing the accuracy of the orbit computed by Dr. Chandler. Not until 1924 does so favorable opposition again occur; but in December, 1900, it will approach us within 31 millions of miles, or about 4 million miles nearer than Mars ever does. This opposition will give a new and very accurate value of the solar parallax, because of the precision with which a diskless object of this sort can be measured. The opposition of 1924 will provide a value of the Sun's distance far exceeding in accuracy that from all other methods now available. Probably Eros is less than 20 miles in diameter, and its close approach to the Earth, every thirty years will introduce perturbations of its motion of great intent to gravitational astronomers. It consumes $1^{3}/_{4}$ years in journeying once completely around the Sun; and its variation between such wide extremes of distance suggests many important problems to the astrophysicist.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and to write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the tenth of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are our sole European agents.

Subscription Price to Popular Astronomy in the United States, Canada and Mexico is $2.50 per volume of 10 consecutive numbers. Price per volume of 10 numbers to foreign subscribers $3.00.

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Northfield, Minn., U. S. A.